ID: 88081759

Box 1
1-10

USDA United States
Department of
Agriculture

Forest Service

Inventory and
Monitoring Institute
Report No. 4

October 2002

MONITORING FOR FOREST MANAGEMENT UNIT SCALE SUSTAINABILITY:

THE LOCAL UNIT CRITERIA AND INDICATORS DEVELOPMENT (LUCID) TEST

TECHNICAL EDITION

Wright, P. A., G. Alward, J.L. Colby, T.W. Hoekstra, B. Tegler, and M. Turner. 2002. *Monitoring for forest management unit scale sustainability: The local unit criteria and indicators development (LUCID) test (technical edition).* Fort Collins, CO: USDA Forest Service Inventory and Monitoring Report No. 4. 370 p.

For additional information contact:

USDA Forest Service
Inventory and Monitoring Institute
2150 Centre Ave., Bldg. A, Suite 300
Fort Collins, CO 80526
Phone: 970-295-5740
Fax: 970-295-5885

Note: The use of trade names is for the benefit of the reader; such use does not constitute an official endorsement or approval by the USDA Forest Service to the exclusion of others that may be suitable.

USDA FS IMI Report No. 4 2002

MONITORING FOR FOREST MANAGEMENT UNIT SCALE SUSTAINABILITY:

THE LOCAL UNIT CRITERIA AND INDICATORS DEVELOPMENT (LUCID) TEST

TECHNICAL EDITION

Principal Author
Pamela A. Wright, Ph.D.[1]

Contributing Authors
Gregory Alward, Ph.D.[2]
Thomas W. Hoekstra, Ph.D.[2]
Brent Tegler, Ph.D.[3]
Matt Turner, M.S.[2]

---

[1] USDA Forest Service Inventory and Monitoring Institute/METI, Inc., Fort Collins, CO.
[2] USDA Forest Service Inventory and Monitoring Institute, Fort Collins, CO.
[3] North South Environmental Consultants, Ontario, Canada.

PREFACE

The Forest Service has a strong commitment to its motto: “Caring for the Land and Serving People.” Monitoring for sustainability of our national forests and grasslands, as a result of ecosystem management, is a key component of this commitment. Our goal in the Forest Service is to work with our partners, the American public, to strike the right balance between sustainable ecological, social, and economic systems. In this way we can satisfy the values of the present without compromising the needs of future generations.

This report documents the second major step the Forest Service has taken to establish sustainability monitoring on national forests and grasslands. In the first project, completed in 1999, the Inventory and Monitoring Institute (IMI) tested the application of the Center for International Forestry Research (CIFOR) forest management unit scale “Criteria and Indicators of Sustainability.” The Boise National Forest, Forest Service Research, and International Programs cooperated in this effort. While the CIFOR project showed very promising results for the application of sustainability assessments on national forests and grasslands, it also highlighted the need for a more thorough test of the methodology in a variety of ecological, social, and economic settings.

In 1999, the Chief’s office asked the IMI to undertake the Local Unit Criteria and Indicators Development (LUCID) project. This report, and supporting documentation, is now available to assist and guide the development of sustainability assessments on national forests and grasslands, as part of the planning process. The LUCID monitoring methodology will continue to evolve, as national forests and grasslands tailor sustainability assessments to local ecological conditions, and to meet the needs of collaborators in both public and private venues. There is not a single sustainability assessment for all national forests and grasslands. The LUCID test has identified common ecological, social, and economic threads that can be woven together to tell the sustainability stories of our national forests and grasslands. Sustainability is the common ground between all public values. Sustainability assessments provide the information that we, and the American people, can use to assure the continued long-term integrity of the ecological, social, and economic systems we depend on from the lands we manage. I am proud to convey this report to the Forest Service and to the American people. Sustainability assessments provide a blueprint for us to use as we work together toward the next 100 years of public land management.

DALE N. BOSWORTH
Chief

ACKNOWLEDGMENTS

The LUCID Project was initiated as a result of the Center for International Forestry Research–North American (CIFOR–NA) Test in Boise, Idaho in 1998. The United States Department of Agriculture Forest Service Research and International Programs, who sponsored the original CIFOR-NA test, continued to advocate for, and support, the LUCID Project from the outset. We benefited in many ways from the strong work of the Center for International Forestry Research, particularly the assistance of Dr. Ravi Prabhu.

The LUCID Project was a true partnership between the forests and the Washington Office. The eight national forests, participating in six forest teams, took the germ of an idea and a rough protocol and worked together with the IMI, with their collaborators, and with each other. They were constantly innovating, providing constructive comments with good humor, and were always willing to go the extra mile. Most teams were developed through strong partnerships with universities, or staff from other national forests and regional offices; these individuals provided fresh ideas and alternative perspectives that were very helpful.

The forest supervisors and deputy forest supervisors for the Allegheny, Malheur, Modoc, Mt. Hood, Ottawa, Wallowa-Whitman, Tongass, and Umatilla National Forests were advocates for their forest teams and played an active role throughout the project. We thank in particular the Allegheny National Forest leadership team who strongly supported the project during several forest supervisor transitions. Each of these forests also benefited from strong support of the regional foresters and State foresters who supported the project from its initiation.

The Boise National Forest, the host for the 1998 CIFOR-NA test, continued to play a valuable role in the LUCID Project. At their own initiation and in conjunction with the other forests in the Southwest Idaho Ecogroup, the Boise National Forest was able to implement some of the preliminary ideas for incorporating sustainability monitoring into their forest plan revision. We thank in particular Lynnette Morelan and David Rittenhouse who championed this initiative and participated in the LUCID Project in a review capacity and were always willing to make presentations to those interested in implementation realities.

A number of people from both inside and outside the Forest Service provided valuable suggestions, support, and review comments throughout the project including: Washington Office Ecosystem Management Coordination staff; Michael Sieg, Field Sampled Vegetation staff; Andrew Gillespie, Forest Inventory Analysis; Connie Carpenter, State and Private Forestry; Great Lakes Forestry Association staff and volunteers; Brad Holt, Boise Cascade Industries; staff and volunteers with the Canadian Model Forest Network; and the whole staff of the IMI. Ravi Prabhu, Timothy Allen, Joseph Tainter, Donald Floyd, and Stephen Woodley provided very useful review comments.

Elizabeth Reite, graduate student at Colorado State University, provided assistance in many, many capacities. Beth helped prepare databases and publication material, provided great suggestions for revisions, and was always willing to do whatever needed to be done.

We wish to specifically thank Management and Engineering Technologies International, Inc. (METI), particularly Renard and Al Johnson who managed and coordinated staffing, keeping all of us happy and well supported. METI staff were consummate professionals and were always interested in what we were doing and in finding ways they could help.

We would like to extend special thanks to those individuals who helped us pull all the details of the report together:

- Original cover art and figures: Joyce VanDeWater, USDA Forest Service Rocky Mountain Station
- Database and computer models: Richard Hagestedt, Mt. Hood National Forest
- Editor: Kevin Cook, Fort Collins, CO
- Layout and design: Carol LoSapio, USDA Forest Service CAT Publishing Arts

GUIDE TO THE REPORT

The LUCID Project was a collaborative initiative among eight national forests, their leadership teams, and the Inventory and Monitoring Institute (IMI). Participating personnel all approached the test with a common goal of trying to determine whether FMU-scale sustainability monitoring was feasible and useful and how it could be done. The LUCID Project was comprehensive and the reports have been written for a wide range of audiences both within and outside the Forest Service from forest managers to planners to those involved in implementing monitoring programs to collaborators.

To better serve the interests of our diverse audiences, the results of the LUCID Project are presented in three main parts: the executive summary; the main report; and a detailed criteria and indicator database available on compact disk (CD) or from the Institute's website (www.fs.fed.us/institute/lucid).

This guide describes some of these navigational tools to help you find what you are looking for in the report.

LUCID Technical Edition Report

The intent is that the full report will serve both as a detailed explanation of the results of the LUCID Project and also as a type of desk reference for those exploring the idea of FMU-scale sustainability monitoring. Recognizing that different types of readers will want to focus on different aspects of the report, we have used a range of different organization and presentation techniques including sidebars, a glossary and acronym list; electronic hyperlinks to help you navigate through the document; chapter outlines and summaries; and icons associated with material appropriate to different interest areas.

The report is organized in five broad sections. Section and chapter introductory pages provide a brief overview of the material inside and a guide to the main focus areas.

Executive Summary

The Executive Summary is oriented towards managers and provides highlights of the background and methods of the project and focuses on the management implications of the project[1].

Section 1. Background and Context

Sets the context for the LUCID Project with discussions of sustainability, a systems-approach to sustainability, and issues of scale.

Chapter 1. The Path to Sustainability
Chapter 2. A Systems Approach to Sustainability Monitoring
Chapter 3. Scale and Sustainability Monitoring

Section 2. Methods

Presents a brief overview of the methods used in the project including its collaborative and interdisciplinary aspects.

Chapter 4. LUCID Test Methods
Chapter 5. Collaborative Approaches to Sustainability Monitoring

---

[1] Material contained within the Executive Summary is also contained within the full report.

Section 3. Criteria and Indicator Results

Presents the origin, development, and testing of the criteria and indicators through the six forest teams and is supported by the LUCID C&I Resource Database CD. This CD includes a comprehensive database of the descriptions and details for the principles, criteria, indicators, and measures; a starting conceptual model of the C&I built within NetWeaver; and copies of the other report appendixes that support components of the report and testing process.

Chapter 6. Monitoring Hierarchies: The Criteria and Indicators Approach
Chapter 7. Development of the LUCID Systems Frameworks
Chapter 8. Indicators
Chapter 9. Measures and Data Elements
Chapter 10. Reference Values
Chapter 11. A Core Suite of Forest Management Unit Scale Criteria and Indicators

Section 4. Analysis and Synthesis

Addresses approaches, tools, and techniques for analyzing and assessing sustainability.

Chapter 12. Assessing Sustainability: Analysis and Synthesis
Chapter 13. Assessing Sustainability: Analytical Tools and Issues

Section 5. Implementation

Concludes with a discussion of the relationship of FMU-scale sustainability monitoring to other monitoring and forest management processes at a range of scales, recommendations for research and development, and recommendations for implementing a forest management unit scale sustainability monitoring program.

Chapter 14. FMU-Scale Sustainability Monitoring
Chapter 15. Implementation: Recommendations and Conclusions

ICONS

You will also find icons on these section introductory pages that are associated with different focus areas in the report to give you a visual reminder of the content.

Explanation ICON

Background—*Explains the purpose, sets the context, or provides explanation*

Methods—*Methods used or discussion of process aspects of sustainability monitoring*

LUCID Experience—*Presents the results of the LUCID Project*

Tools—*Technical tools for sustainability monitoring*

Management Implications—*Implications for management including recommendations*

LUCID Resource Database CD—*Indicates supplemental material is available on the database*

LUCID C&I Resource Database

The list of principles, criteria, indicators and measures (PCIM) (Appendix 10) names the elements; but additional information is needed to fully describe them. The LUCID C&I Resource Database (Appendix 9) provides descriptions, definitions and details of the C&I and was built from the initial work of CIFOR-NA and the experiences of the LUCID forest teams. This Access™ database is intended to serve as a repository for information about each of the C&I elements in an easily searchable and accessible format. Data element and reference value information are included as a subset of the measures component. This database is a work in progress but it provides a starting place to work from. The CD icon provides a reminder of supplemental information that is contained only on the database.

Inventory and Monitoring institute (IMI) Website

Following the release of the LUCID reports the IMI LUCID website will be revised to provide additional information and tools as they are developed. Please keep your eyes on the website for supplemental information. www.fs.fed.us/institute/lucid.

Pamela Wright, Ph.D.

LUCID Team Leader
Inventory and Monitoring Institute/METI Inc.,
USDA Forest Service

TABLE OF CONTENTS

Executive Summary .... **i-xii**

SECTION 1: BACKGROUND AND CONTEXT

Chapter 1. The Path to Sustainability

Perspectives on Sustainability 4
  Sustaining Outputs or Contexts 5
  Sustainability as a State or a Process 5
  Sustainability or Sustained Yield? 5
  What Scale is Sustainable? 6
  Sustainability of What, Where, for Whom, for How Long, and at What Cost? 6
  Ecological Perspectives on Sustainability 7
  Socioeconomic Perspectives on Sustainability 7
  Defining Sustainability Through an Interdisciplinary Process 9
Sustainability Monitoring 10
  Monitoring and the Adaptive Management Cycle 10
  The Focus on Indicators 11
  Criteria and Indicators for Sustainability 12
  Origins of the C&I Tool 12
  Forest Certification 13
The LUCID Project 14
The LUCID Experience: Benefits from FMU-Scale Sustainability Monitoring 14
  Why the Forests First Participated 14
  Improvements in Collaboration 16
  Emerging Benefits: Process and Product 16
Overview of the Report 18
  Executive Summary 18
  LUCID Report 18

Chapter 2. A Systems Approach to Sustainability Monitoring

Framing the Approach to Monitoring for Sustainability 23
  An Overview of Monitoring Frameworks 23
  The Relationship of Systems Thinking to Sustainability:
    The Value of a Systems-Based Framework 25
  Linkages Between Frameworks 25
An Overview of System Thinking 25
  Emergent Properties: The Whole is More Than the Sum of Its Parts 26
  Systems, Scale and Hierarchy Theory 26
  System Kind or Type 26
  Measurement from What Perspective: The Role of the Observer 27
  Assessing the State of a System 29
The LUCID Experience: Application of a Systems Approach 31
  Adaptation of the Systems Framework at the Pilot Level 31
Implications 31
  Differences Between a Systems Approach and Traditional Monitoring Approaches 31
  Key Advantages to the Systems Approach 32
Chapter Highlights 33

Chapter 3. Scale and Sustainability Monitoring

Background: Multiscale Monitoring 37
  Temporal Scale and Sustainability 39
Multiple Scales: Measurement and Data Issues 39
  Scale-Dependent Measures 40

Scale and Data Aggregation 40
The LUCID Experience: Lessons in Scale 41
The Role of Scale Issues 41
Going Beyond Administrative Boundaries 41
Process: Defining the Boundary of Interest 42
The Boundaries for Analysis 43
Coarse versus Fine Scale 44
Temporal Scale Considerations 46
Chapter Highlights 47

SECTION 2: METHODS

Chapter 4. LUCID Test Methods

Applied Research in Forest Management Unit C&I: The LUCID Test 51
Lessons Learned from Elsewhere 51
Chapter Content 52
Selection of Forest Teams 52
The Value of Six Pilot Tests 53
Methods Overview 54
The Initial LUCID C&I 54
Review, Adaptation, and Development of C&I Through the Test 56
Data Collection 57
Integration and Analysis of Results: Conceptual and Analytical Modeling Tools 57
Reporting 58
Core Team Analysis and Revision 58
Science Review 59
An Interdisciplinary Approach 59
The LUCID Core Team 60
LUCID Forest Teams 60
LUCID Forest Supervisor Team 61
LUCID Experience on Team Composition 62

Chapter 5. Collaborative Approaches to Sustainability Monitoring

Background: The Need for Multiple Perspectives 71
The LUCID Experience 72
Implications 73
Who Should We Collaborate With? 73
Potential Roles for the Public 73
Chapter Highlights 75

SECTION 3: CRITERIA AND INDICATOR RESULTS

Chapter 6. Monitoring Hierarchies: The Criteria and Indicators Approach

Background: The Value and Development of C&I Hierarchical Frameworks 79
Clarifying the Nomenclature of C&I Hierarchies 79
The LUCID Experience: The Principle, Criterion, Indicator, and Measure Framework 80
Common Components of C&I Frameworks 80
Final LUCID Hierarchical Framework for Monitoring 82
Implications 83
Specificity and Consistency 83
Comparisons Between C&I Frameworks 85
Relationship Between the C&I Hierarchy and a Systems Approach: Merging Frameworks 85
Chapter Highlights 87

Chapter 7. Development of the LUCID Systems Frameworks

Background: The Value of a Systems Framework 91
The Process: Development and Revision of Systems Frameworks 92
  Initial Development of the Systems Frameworks 92
  Forest Team Testing of the Core Set of Principles and Criteria 93
LUCID Ecological System Framework 93
  Kinds of Ecological Systems 93
  Structures and Processes of Systems 94
  The Spatial Dimension 95
  LUCID Forest Team Adaptation of the Ecological System Framework 95
  The Final LUCID Ecological Systems Framework 96
LUCID Social System Framework 96
  The Relationship Between Social Systems and Sustainability 97
  The Initial LUCID Social Systems Framework 98
  LUCID Forest Team Adaptation of the Social Framework 101
  The Final LUCID Social System Framework 102
LUCID Economic Framework 104
  Initial Economic Systems Framework 105
  LUCID Forest Team Adaptation of the Economic System Framework 107
  The Final LUCID Economic System Framework 108
Chapter Highlights 111

Chapter 8. Indicators

Background: What is an Indicator? 115
  Integrative Indicators 115
  Inter- and Intragenerational Equity Indicators 115
  Inclusive Development 116
  Indicators or Indices 116
  Outcome-Oriented Indicators 116
  Short- or Long-Term Outcomes: Sustainability for How Long 117
  Management Process and Enabling Conditions Parameters 119
The Process of Development Local-Level Indicators 120
  The Role of Indicators in the LUCID Project 120
  Development of Indicators—Origin of the Core Set 120
  The Method of Adaptation 121
The LUCID Experience: Selection, Revision and Adaptation of Indicators 122
  Social Indicators 123
  Ecological Indicators 126
  Economic Indicators 129
Implications 132
  Management Process and Enabling Condition Indicators 132
  Indicators of Interrelationships 133
  Identifying a Critical Suite of Indicators: How may indicators are too many? 135
Chapter Highlights 139

Chapter 9. Measures and Data Elements

Background: Measures and Data Elements 143
Process: The Approach to Developing Measures 143
The LUCID Experience with Measures 144
  The LUCID Measures: Ecological, Social and Economic 144
  Measures for Different Purposes 145
  Proxy Measures 145
  Incorporating Time into Measures: Sustainability for How Long? 146
  Measures and Spatial Scale 146
  The Use of Indicator Species 147

Application Implications 148
    The Availability of Existing Protocols 148
    Frequency of Monitoring 148
    Data Availability and Challenges 149
    An Evolving Set of Measures 154
    Core or Recommended Measures and Data Elements 154
Chapter Highlights 155

Chapter 10. Reference Values

Background 159
    What is a Reference Value? 159
    Types of Reference Values 160
    Do We Need Reference Values? 161
    Merits of Using Reference Values 162
The LUCID Experience: The Role of Reference Values 163
Implications for Future Use of Reference Values 164
    Suggestions for a Revised Process 164
    Fuzzy Logic and Reference Values 169
    The Temporal Dimension to Reference Values 170
    Spatial Variability and Reference Values 170
    Sources and Availability of Reference Values 170
    Consistency and Flexibility 171
    Remaining Challenges 171
Chapter Highlights 172

Chapter 11. A Core Suite of FMU-Scale Criteria and Indicators

Background 175
The Process 175
    Development of a Core Suite of FMU Scale C&I 175
    Decisions and Assumptions in the Development of the Final C&I 176
The LUCID Experience: The Final Suite of FMU Scale C&I 176
    Principles and Criteria 177
    Indicators 177
    Measures, Data Elements and Reference Values 177
    Preliminary Relationships with Corporate Data Sources 181
    Supporting LUCID C&I Resource Database 183
Chapter Highlights 184

SECTION 4: ANALYSIS AND SYNTHESIS

Chapter 12. Assessing Sustainability: The Analysis Process

Background: Assessing Sustainability 187
    The Critical Questions 187
    Synthesis and Analysis 188
    Assessment vs. Determination 188
The LUCID Experience with Synthesis and Analysis 188
    Conceptual Models 189
    Assessment Approaches for Synthesis and Analysis 193
    Analysis and Synthesis with Numbers and Narratives 197
Chapter Highlights 201

Chapter 13. Assessing Sustainability: Analytical Tools and Issues

Background 205
Key Features 205
    Knowledge/Logic-Based Models 206
    Knowledge-Based Model Components in NetWeaver 206
    Hierarchically Constructed 208

Hierarchical Attributes of NetWeaver 208
Object-Oriented 209
Object-Oriented Attributes of NetWeaver 209
Spatially Application 210
Spatially Based Requirements of NetWeaver: The GeoNetWeaver Extension 210
A Range of Reference Values: Discrete and Fuzzy Reference Values 212
Fuzzy Logic and NetWeaver 212
Weighting 213
Weighting and NetWeaver 213
Incomplete Models and Missing Data 216
Treatment of Missing Data in NetWeaver 216
Transparency and Documentation 217
Transparency and NetWeaver 217
Interactive and Adaptable 218
Real-Time Modeling and NetWeaver 218
Compatibility 219
NetWeaver and GeoNetWeaver Compatibility with US Forest Service Systems 219
Synthesis and Integration Issues 221
Synthesis and Integration within the LUCID Project 223
Implications 226
Is it possible to conduct a sustainability assessment without the use of technical modeling tools? 226
Do we need one tool that will perform all of the functions? 227
Where do we go from here? 227
Chapter Highlights 228

SECTION 5: IMPLEMENTATION

Chapter 14. Forest Management Unit Scale Sustainability Monitoring

FMU-Scale Sustainability Monitoring: The Adaptive Management Feedback Loop 231
Forest Planning, Management and Monitoring 232
Application to Daily Work and Project-Level Activities 234
Contributions to Multiscale Monitoring 235
The Value and Meaning of Multipurpose - Multiscaled Relationships 235
Regional-Scale Assessments 237
National Framework for Sustainable Forests: The Montreal Process C&I 238
Criteria and Indicators and Certification 241
Criteria and Indicators 242
Certification 243
Similarities 244
Differences 244
Different but Complementary 246
Independent Verification: The Potential for Third-Party Auditing 246
What is the benefit or value of third-party auditing of public lands? 247
What is the appropriate scale or application? 247
How feasible is a third-party auditing extension to C&I monitoring? 247
Chapter Highlights 248

Chapter 15. Implementation: Recommendations and Conclusions

The Value and Utility of FMU-Scale Sustainability Monitoring 251
Valuable Information within an Adaptive Management Approach 251
Identifying Critical Issues 252
Providing a Forum for Discourse 253
Strategic Implementation Issues 253
Key Features of FMU-Scale Sustainability Monitoring 253
The Feasibility of FMU-Scale Sustainability Monitoring 255

Consistency and Flexibility 257
Sustainability Monitoring as an Addition, Supplement, or Replacement: Strategic Implementation Highlights 260
Tactical Implementation Issues 261
A Vision for Implementation 261
A Revised Process for FMU-Scale Sustainability Monitoring 261
Resources Required for Implementation 263
Timing Considerations 265
Tactical Implementation 267
Research Recommendations 269
Conclusions 272

Bibliography 273
Acronyms 281
Glossary 283

LIST OF APPENDIXES

Appendix 1 A Summary of the Some of the International and National Commitments to Sustainability 287

Appendix 2 Agenda 21: Rio Declaration 289

Appendix 3 Santiago Declaration 295

Appendix 4 LUCID Pilot Test Interim Products and Tasks 301

Appendix 5 The Ottawa LUCID Pilot Process by Major Pilot Task 303

Appendix 6 Initial LUCID Criteria and Indicators List and Source Comparison 305

Appendix 7 Indicator and Verifier Development Form 323

Appendix 8 LUCID Team Descriptions 329

Appendix 9 LUCID Criteria and Indicators Resource Database (on CD only) 331

Appendix 10 Final Suite of LUCID Principles, Criteria, Indicators, and Measures 333

Appendix 11 Tools to Assist in Conceptual Model Development 349

Appendix 12 NetWeaver Model (on CD only) 353

Appendix 13 Reporting and Presentation Ideas 355

Appendix 14 Technical Issues in Weighting 357

Appendix 15 Montreal Process Criteria and Indicators 363

Science Review Supplement 367

LIST OF TABLES

Table 1. Boundaries for Analysis in the LUCID Tests 44

Table 2. Scales of Analysis in the LUCID Tests 44

Table 3. Example of Comparison Between the Initial LUCID C&I and Other Indicators Tracing Origin and Overlap (See Appendix 6 for the full table) 55

Table 4. Primary Team Composition by Source and Area of Expertise 61

Table 5. Components of the LUCID Hierarchical Framework for Monitoring 83

Table 6. Comparison of the number of hierarchy levels and the level names used in monitoring programs to assess sustainable forest management (FAO 2001) 85

Table 7. Nomenclature Comparison Between Montreal Process and LUCID C&I Frameworks 86

Table 8. Comparison of Ecological Criteria Between LUCID Core and LUCID Forest Teams 95

Table 9. Summary of Components of Social Sustainability Conceptual Frameworks 97

Table 10. Comparison of Social Criteria Between Initial LUCID Core and LUCID Forest Teams 101

Table 11. Some Socioeconomic Components of Sustainability 106

Table 12. Comparison of Economic Criteria Between LUCID Core and LUCID Forest Teams 108

Table 13. Terms and Definitions Used to Categorize Indicators by Type 117

Table 14. A Summary Comparison of the Initial and Final LUCID Social Criteria 123

Table 15. Comparison of Final to Initial Social Indicators 124

Table 16. A Summary Comparison of the Initial and Final LUCID Ecological Criteria 126

Table 17. Comparison of Final to Initial Ecological Indicators 128

Table 18. A Summary Comparison of the Initial and Final LUCID Economic Criteria 129

Table 19. Comparison of Final to Initial Economic Indicators 130

Table 20. Comparison of Indicator Numbers Between C&I Suites 138

Table 21. Common Data Sources Used by LUCID Forest Teams 149

Table 22. Sample of Possible Key Questions to Guide Economy Analysis 197

Table 23. Desired Key Features 205

LIST OF FIGURES

Figure 1. An application cycle for adaptive management 10

Figure 2. International Forest Sustainability Effort 13

Figure 3. Locations of the LUCID Forests and CIFOR-NA Site 15

Figure 4. Ecological System Kind and Spatial Scale 27

Figure 5. An illustrative full system composed of two entities with three parts each. This complete system is not observable from any single observational perspective 27

Figure 6. The person is making the observation from within the entity and can observe the parts and their interactions, an example of "fine grain" observation. (The eye indicates the position from which the system is observed.) 28

Figure 7. When the person moves outside the system, he or she can observe the phenomena at a broader level. In this case the observations can be classified as "coarse grain." 28

Figure 8. Mt. Hood National Forest Watersheds and Communities 45

Figure 9. Relationshed Zones of Influence 46

Figure 10. Testing of the Initial Suite of C&I 56

Figure 11. Schematic of LUCID Hierarchical Framework 81

Figure 12. Dimensions of the PCIM Hierarchy 84

Figure 13. Sustainability is a product of the components and interactions between the three systems 92

Figure 14. LUCID Ecological Systems Framework: The eight criteria are the result of the combination of the kind of system with the structure and functions of systems. 95

Figure 15. The Initial LUCID Core Social System Framework 99

Figure 16. The Final LUCID Core Social System Framework 102

Figure 17. The Initial LUCID Core Economic System Framework 105

Figure 18. The Final LUCID Core Economic System Framework 110

Figure 19. Indicator Evaluation Options 121

Figure 20. Sample of a Portion of an Entry for a Measure in the LUCID Resource Database 141

Figure 21. Summary Scores for the Environment Benchmarks for the Oregon 2001 Benchmarks Performance Report (Oregon Progress Board 2001) 159

Figure 22. Social Criteria and Indicators 178

Figure 23. Ecological Criteria and Indicators 179

Figure 24. Economic Criteria and Indicators 180

Figure 25. Example of the Types of Measures Associated with Indicators 181

Figure 26. Conceptual Model of the Aspen-Deer Issue on the Ottawa National Forest 190

Figure 27. Developing a Preliminary Conceptual Map of the Ecological Sytstems 192
Figure 28. Conversion of the Rough Conceptual Map to C-Map 192
Figure 29. Example Indicator Summary 193
Figure 30. Narrative Discussion of Interrelationships: Ottawa Forest Team Discussion Points for a Social 195
Figure 31. Display of Spatial Variation of a Hypothetical Indicator Compared to its Reference Value 196
Figure 32. Tongass National Forest Display of NetWeaver Results from the Social Principle 196
Figure 33. Modoc National Forest: Example Ecological Indicator Narrative with Management Implications 200
Figure 34. Example LUCID Dependency Network 207
Figure 35. Hierarchical Representation of the PCIM within NewWeaver 208
Figure 36. Object Oriented 209
Figure 37 Spatially Based Features of GeoNetWeaver 211
Figure 38. Fuzzy Reference Values 212
Figure 39. Data Sufficiency 216
Figure 40. Meta-Data Documentation Form within NetWeaver 217
Figure 41. What-if Scenario Modeling 218
Figure 42. Classification of Sustainability Index 220
Figure 43. Dashboard of Sustainability 222
Figure 44. Ecosystem Well-Being 222
Figure 45. Oregon Benchmarks Report Card 226
Figure 46. The role of monitoring in adaptive management 231
Figure 47. Subset of SWI Ecogroup Indicator Analysis for Forest Plan 233
Figure 38. Relationship Between Multiscale Monitoring for Different Purposes 241
Figure 39. Consistency and Flexibility Issues Associated with C&I 257
Figure 50. Revised Process for FMU Scale Sustainability Monitoring 262

MONITORING FOR FOREST MANAGEMENT UNIT SCALE SUSTAINABILITY:

THE LOCAL UNIT CRITERIA AND INDICATORS DEVELOPMENT (LUCID) TEST

EXECUTIVE SUMMARY

Every day throughout the United States, and indeed the world, people seek to find places to sustain their spirit like the imagined environment on the cover of the report. A place where a fisher can find the quiet solitude of a mountain lake and an abundant catch of trout. Where a group of friends can escape from the city for the day to mountain bike on a rugged rocky trail. A place with clear flowing streams and healthy meadows where the rancher takes his cattle each spring. A place where a Native elder can—within her traditional territory—pick huckleberries and gather bear grass for her family. This is the place where the late afternoon sun finds the ranger on her way to a community meeting on the prescribed fire plans stopping to help a crew of Scouts unload a wheelbarrow of gravel for the hiking trail. A place where fathers, sons, and uncles can revisit in time-honored tradition the hunting camp and the quest for a mythical encounter with a buck. This is the place—the distant vista of velvet green forests and dramatic mountain peaks—that is the "million-dollar-view" the realtor describes to the couple apartment hunting in the city. It is an open forest of ponderosa pine, a forest of towering Douglas-fir, or a forest of quaking aspen where morning finds a crew of loggers with saws and cables on their shoulders and a careful set of eyes marking the fall lines and the reserve for the osprey nest. This place provides the fine dark cherry for the cabinetmaker, the clear strong pine boards for the builder, and—in a hundred different ways—groceries for the table. This place is honored by decades of photos in the family album as the best place to find the perfect Christmas tree.

THE QUEST FOR SUSTAINABILITY

Chapter 1

No hypothetical place, this description is a collage of genuine images from our national forests. It portrays the collective journey we have undertaken to find a way to live harmoniously with each other and with our environment. The journey is a quest for sustainability.

The term "sustainability" expresses the human desire for an environment that can provide for our needs now and into the future, across many generations. However, what the term implicitly conveys and what it explicitly means are not necessarily the same. Finding a specific definition of sustainability on which we can all agree is difficult—some would say it is a pointless quest—because it is about values, which vary between groups and over time. Paradoxically, the things we decide to sustain have value only because we do value them.

Developing a Language of Sustainability

The quest for sustainability is about deciding what to sustain, for whom, for how long, at what cost, and how. Yet, with all its uncertainties and criticism, sustainability as an idea has widespread appeal and is the term that has emerged to encapsulate our collective thinking. It represents the beginning of a dialogue and the development of a new and shared vocabulary.

Nowhere has the struggle for sustainability and the development of this dialogue been more focused than in relation to forests. The sustainability of tropical and temperate forests has brought the dialogue about sustainability into our backyards. Within the United States many agencies, industries, organizations, and citizens have engaged in the quest for sustainability through various initiatives. The LUCID Project presents the results of one initiative: a United States Department of Agriculture Forest Service project to develop a sustainability-monitoring program for the Forest Management Unit (FMU) scale.

THE CRITERIA AND INDICATORS MONITORING FRAMEWORK

Chapters 1 & 6

Monitoring has emerged as one of the primary management responses to the sustainability challenge; placed within an adaptive management context, monitoring engages us in a systematic and rigorous learning exercise. Consequently, monitoring is not independent from the larger land management process but becomes the core—the essential feedback loop—of managing for sustainability.

Criteria and Indicators (C&I) is a name for frameworks designed to help provide a common understanding of what is meant by sustainable management and to frame the monitoring process. Given the abstract nature of the sustainability concept, the hierarchical framework of C&I is intended to elucidate, step-by-step in a logical way, the goals of sustainability. Monitoring provides the essential feedback information regarding sustainability, but the information is useful only if it is the right kind. Acquiring useful information depends on establishing the appropriate criteria and selecting the right indicators. The most desirable framework integrates diverse system components and avoids unconnected indicators.

Numerous national governments, international declarations, forest management units, and forest certifying bodies use C&I frameworks to structure monitoring efforts. The most widely known use originated with the 1992 United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro. As a result of the UNCED-Rio conference and the subsequent Agenda 21, declaration (see Appendix 1) an initiative was launched to develop C&I for the sustainable management of temperate and boreal forests. The Working Group on Criteria and Indicators for the Conservation and Sustainable Management of Temperate and Boreal Forests (referred to as the "Montreal Process") was formed to advance the development of internationally accepted C&I for temperate and boreal forests at the national scale. The Montreal Process C&I is intended to provide a common understanding of what is meant by sustainable forest management and to provide a common framework for describing, assessing, and evaluating a country's progress toward sustainability.

A Need for Forest Management Unit Scale Criteria and Indicators

Chapter 3

Although much of the initial focus on C&I came from the need to report both nationally and internationally on sustainable forest management, there was growing realization that sustainability issues are multiscaled and that the national goals of sustainability rest, in large part, on the actions that are carried out at the FMU scale. The need for FMU-scale C&I initiatives arose, not because of the imposition of top-down needs, but, out of the recognition that local-unit monitoring and reporting were essential to understanding and achieving sustainability.

The FMU scale can generally be described as the scale at which management policy is actually implemented with on-the-ground activity and at which one or more ownerships decide how a land area will be affected by land and resource management activities. Total land area and ownership size might vary, but the focus on the FMU scale is based on the assumption that it is at the FMU scale that most of the decisions about management occur. The design of FMU scale C&I is intended to help provide insight into the sustainability of the underlying ecological, social, and economic systems that function coincident with the FMU scale.

Recommendations from the Center for International Forestry Research—North American Test (CIFOR-NA)

As a first step towards using FMU-scale C&I in North America (NA), the Forest Service and the Center for International Forestry Research (CIFOR) conducted a test in an area including the Boise National Forest in 1998. Government, industry, and nongovernmental organizations from Canada, Mexico, and the United States participated. The CIFOR-NA test refined and adapted the global CIFOR C&I set to the ecological, social, and economic conditions of North America. An important outcome of the CIFOR-NA test was recognition that local-scale C&I can provide the information needed for sustainable management of national forests. Some of the test conclusions are as follows (Woodley et al. 2000):

- Indicators developed for application at other scales "do not translate well to the forest management unit" scale and consequently are not as valuable in informing management.

- Reliance only on available data in indicator development undermines the indicator concept.
- Management C&I (e.g., enabling condition indicators) are less useful in the Forest Service context at the FMU scale as there are an extensive set of legal and institutional structures that govern forest management.
- Indicators need to be "referenced against a target;" however, norms and standards have not consistently been used to date in most suites of C&I.
- A clear hierarchy and terminology for C&I is needed to frame the development of indicators.
- C&I needs to be well documented and referenced to ensure their utility in the long run.
- Operational issues associated with the use of indicators need to be addressed.
- The issues of analysis and the interrelationship of the indicators still need work. Systems frameworks proposed by Hoekstra et al. (1998) to the CIFOR-NA provide a basis for integration and the [CIFOR-NA] team recommends the pursuit of "this line of reasoning as a research focus."

A Charter for the LUCID Project

Based on this preliminary test, the Forest Service Local Unit Criteria and Indicators Development (LUCID) test was chartered by Forest Service Chief Mike Dombeck following the 1998 North American Forestry Commission meeting. The intent of the LUCID Project was to work with personnel at six test sites and thereby expand the science-based evaluation to develop a forest-scale monitoring program for sustainable ecological, social, and economic systems.

> *"It is time to move the debate over C&I from national policy forums to the field management unit. At their core, C&I are practical applications of knowledge. We must remember to focus on their practicality. Otherwise we will ignore many pressing and real problems while we get the science right."*
> (Woodley et al. 2000)

SYSTEMS APPROACH

Chapters 2 & 7

Building on the results and recommendations of the CIFOR-NA test, the monitoring approach for the LUCID Project was framed within a systems context. Systems-based frameworks draw from the three main components of sustainability—ecological, social, and economic—and indicators are organized within these domains based on systems theory. Systems theory suggests that systems are a group of interrelated, interacting, or interdependent constituents forming a complex whole. A systems-based framework uses the structures and functions of the systems as the organizing tools. A systems approach focuses on the contexts that allow for the production of goods, services, and opportunities to meet different values.

Within a systems approach the focus is on the outcomes, or states of systems, and not on inputs or outputs. This is particularly applicable to forests since they are joint production systems that simultaneously, not independently, produce soil, water, air, plant, and animal material. This framework is most effective for ensuring coverage of the three systems from which sustainability emerges and for examining interactions within and among the three main components of sustainability.

The systems approach was hypothesized to be useful in two primary ways: first, it would better define the items for inventorying and monitoring; and second, it would provide an integrative model for synthesis and analysis of the inventory data. A systems approach establishes a logical link from sustainability to monitoring as it helps place the monitoring component in context. From a process perspective the systems framework is very useful because it provides a common starting point for collaborators and a means of building a common language about sustainability.

METHODOLOGICAL APPROACH

Chapter 4

The purpose of LUCID was to conduct a pilot study that would appraise the feasibility of monitoring sustainable systems at the FMU scale; to provide forest managers and collaborators with feedback that can be used to improve Forest Land Management Plans; to enhance collaboration between national forests and other governmental agencies; and to relate forest plan outcomes with regional and national C&I trends. Five specific objectives were set to guide the project:

1. Test, develop, modify, and evaluate C&I to assess the sustainability of ecological, social, and economic systems at the FMU scale;
2. Develop analysis methods that establish the relationships between indicators and aggregate the results for reporting on sustainability;
3. Examine the relationship between national-scale (e.g., Montreal Process) and FMU-scale indicators;
4. Develop a research agenda based on the above work to further understanding and application of FMU-scale C&I; and
5. Develop a strategy to implement FMU-scale C&I throughout the Forest Service.

Six Tests Across a Range of Conditions

Six interdisciplinary teams working on eight national forests were active in the LUCID Project: Ottawa National Forest in the Upper Peninsula of Michigan; Allegheny National Forest in northwestern Pennsylvania; Modoc National Forest in northern California; Blue Mountains Province Forests of eastern Oregon (including Wallowa-Whitman, Malheur, and Umatilla National Forests); Mt. Hood National Forest in northwestern Oregon; and Tongass National Forest in southeastern Alaska. LUCID test sites ranged from 500,000 acres to 17 million acres and from a single national forest to three national forests working within one ecoregional province. In keeping with ecological, social, and economic systems, the study areas were not just limited to national forest system lands.

During an approximately 2-year period, a coordinating team from the Forest Service Inventory and Monitoring Institute (IMI) worked with each participating national forest. Both the IMI core team and the forest teams required a mix of skills to carry out this task. Ideally, this meant that each team was composed of a ecologist, sociologist, and economist to address the content components, as well as an analyst/GIS specialist to address the data management, modeling, and technical aspects. LUCID forest supervisors also participated actively in the test to provide policy insight on sustainability monitoring and made recommendations on implementing FMU-scale sustainability monitoring.

A Collaborative Learning Approach

Chapter 5

As an applied research project, the teams worked collaboratively using a workshop forum at each major step of the process. Between workshops the forest teams worked more independently, consulting with the core team and with others as needed. The development, analysis, and implementation of a practical set of local-unit C&I involved discussions with many affected groups. These included staff from the Forest Service, staff from other Federal agencies administering public lands adjoining the involved national forests, staff from State agencies responsible for administering State interests, and residents who were local stakeholders at each participating national forest.

Each of the forest teams reviewed a draft set of C&I developed within a systems framework to accomplish the following:

- Develop FMU-specific criteria, indicators, measures, and reference values adapted to the unique conditions of each forest;
- Develop and design the application of reference values to indicators;
- Apply their C&I set in actual field tests using available data;
- Evaluate tools to aid in the analysis and synthesis of the ecological, social, and economic spheres of sustainability;
- Conduct a sustainability assessment to identify areas that are contributing to the sustainability of the ecological, social, and economic systems and identifying areas that may be improved through adaptive management.

The Value and Benefit of Forest Management Unit Scale Sustainability Monitoring

Chapter 14

Forest-scale sustainability monitoring can provide both a process and a tool to help transform the concept of sustainability into "real outcomes on the ground" (Bosworth 2001) by engaging people in a dialogue about what they mean by sustainability. Building relationships between sustainability efforts across ideas, approaches, and temporal and spatial scales is an important part of an overall strategy for improving management of sustainable systems.

> *"So how do we manage for sustainability in the 21st century? What is different? Sustainable resource management means connecting environmental, social, and economic concerns in dealing with real issues in real places with real people... We need to improve our capability to apply locally what we know, and we must integrate our efforts at different scales."*
>
> (Bosworth 2001)

The Core of Forest Plan Monitoring

Current forest plan monitoring is guided in part by the National Forest Management Act (NFMA) and includes minimum legally required monitoring activities supplemented by other monitoring items relevant to the forest. There is a great deal of inconsistency between monitoring activities on national forests and grasslands but most have a dominant focus on forest plan implementation monitoring and a tendency to focus on short-term outcomes.

Generally, forest plan monitoring has been "either systems-based" or systematic in nature. It typically focuses on the presentation of data for individual components instead of the synthesis of components to encourage understanding of complex systems. As a result, the utility of forest plan monitoring to management is at best piecemeal.

As a result of the test projects, LUCID participants from forest supervisors to forest team members concluded that systems-based monitoring for FMU-scale sustainability is feasible and can make significant contributions to improving forest service management. Systems-based sustainability monitoring provides a common framework to help organize and frame monitoring activities that can be applied consistently across the national forest system. FMU-scale sustainability monitoring should serve as the core of the forest plan monitoring activities. Specifically, FMU-scale sustainability monitoring can be used for the following:

- To form the core of the monitoring activities for forest plan monitoring;
- To perform an analysis of existing system conditions—traditionally referred to as the Analysis of the Management Situation (AMS)—as preparation for forest plan revision;
- As a common set of criteria and indicators to compare alternative options on equal footing and with a common language;
- For periodic assessment of the state of systems;
- To facilitate dialogue and engage collaborators in a discussion of a relative assessment of sustainability;
- To provide a trigger or early warning of the need for change in the management plan or for more detailed analysis;
- To provide higher consistency in monitoring activities from forest to forest to facilitate understanding among the public; and
- To organize and contribute to our understanding of sustainability at other spatial scales (e.g., subregional, national, and international reporting initiatives).

Some people view C&I initiatives in two distinct phases: monitoring and assessment. The monitoring component is an ongoing inventorying of a suite of indicators that are tracked over time to identify trends. The assessment process is the phase of interpreting and analyzing the monitoring data against a set of reference value conditions. However, the repeated collection of monitoring and inventorying information has limited value without an analytical or assessment phase. Throughout the report we use the term *sustainability assessment* to mean the interpretation and analysis of sustainability monitoring information.

A sustainability assessment using the suite of C&I can provide a comprehensive way of looking at the state of systems, as well as the state of our knowledge, in preparation for forest plan revision. An assessment provides a way of analyzing the current state of the systems and facilitating understanding of the place of the national forest in the larger context and in identifying the need for change.

Identifying Critical Issues

Beyond providing a broad-based feedback loop for management, FMU-scale sustainability monitoring was identified as a valuable tool to help identify critical issues for further examination of management attention. Sustainability monitoring can be used to flag system elements or areas that need further investigation. When a concern is flagged through the comparison of current data values against reference values, it may lead to more detailed analysis of supporting and supplementary information about the phenomena; it may focus management attention in watching trends more carefully over time; and it may result in a reexamination of the model assumptions, data issues, or appropriateness of the reference values.

Application to Daily Activities

LUCID participants noted that the tool and techniques have application on a daily basis at a range of scales. At the project level it provides a context and a frame of reference and is an entry point to discuss and reveal values.

Learning About Sustainability

One of the key findings was that the process of engaging the national forest staff and collaborators in a dialogue about sustainability and sustainability monitoring was invaluable. The steps involved in the process of developing and implementing a monitoring program for sustainability assessment at the FMU scale emerged as important as more tangible products such as a list of criteria and indicators.

Providing a Forum for Discourse

Criteria and indicators, and the systems framework, provide a basis for developing a common language to talk about the diverse values people hold for sustainability. Forest-scale sustainability monitoring can provide both a process and a tool to help transform the concept of sustainability into "real outcomes on the ground" by engaging people in a dialogue about what they mean by sustainability.

CONTRIBUTIONS TO MULTISCALE MONITORING

Sustainability is a multiscaled problem; consequently, there is no right scale to assess or manage for sustainability. Although sustainability can be studied at multiple scales, once the components of systems are identified for monitoring, selecting the correct scale is critical. The context of the systems that we are trying to sustain change at every scale since the constraints change. Using the wrong scale to look at certain system properties would be like trying to see an elephant through a microscope. So although managing for sustainability requires thinking across all scales, monitoring and assessing sustainability must be based on the recognition that there are different questions and different methods used at different scales.

Examination of the relationships between FMU-scale sustainability monitoring and other scale initiatives requires consideration of the nature of human values and the role of communities interested in forming our values; the nature of living systems and the inherent variability in their form and expression; and the methodological challenges associated with data integrity, sampling, and aggregation.

Relationship to Regional Assessments

In their current configuration, regional assessments have a range of different purposes with some focusing more directly on sustainability and others focusing only on a subset of sustainability issues (e.g., ecological aspects). The monitoring components of these various regional assessments vary considerably from those with monitoring frameworks more consistent with systems-based approaches (e.g., Sierra Province Assessments Monitoring framework) to those with monitoring frameworks constructed to emulate the administrative sustainability monitoring programs of the Montreal Process (e.g., Great Lakes Assessment).

In the future, regional-scale sustainability assessments could fill a unique niche in understanding and managing for sustainability. Regional sustainability assessments provide a unique lens to look at the cumulative effects of management for sustainability at the FMU scale and to understand the larger context of FMU systems. In order to fill this objective, regional sustainability assessments could implement a coarse application of the FMU-scale sustainability monitoring criteria and indicators. Regional assessments may also include other kinds of systems (e.g., regional economies and biomes) best assessed across broader spatial scales than at the FMU scale. Optionally, regional assessments could be supported by data collected uniquely to support this specific scale of assessment and focusing on the scale-dependent questions of the region.

Relationship to National Framework Criteria and Indicators

National and FMU-scale C&I programs represent complementary tools that can be used in our quest for sustainability. Each tool helps answer a set of questions and provides feedback for different kinds of purposes and decisions at different scales.

A strong national framework provides the policy context and structures to enable on-the-ground management for sustainability. The results of national sustainability reporting, for example, may identify broad trends and trigger interest and attention on specific issues. Likewise, improvements in the state of the nation's progress towards sustainability are facilitated by actual changes on the ground. There is clear philosophical overlap and interdependence between the two initiatives although the purposes, tools, and approaches are by intent different and therefore not easily translated one to the other.

Many of the indicators included in national and FMU-scale C&I initiatives are conceptually similar. In some cases not only are the indicators the same, the questions that would be addressed are similar enough between scales that the same measure could be used to verify the indicator. However, although the same piece of raw data may be used at multiple scales, the sampling locations, intensity, and kind of analysis will vary because the sustainability question will change between scales. Where shared data elements can be identified between scales, monitoring efficiencies can be achieved. Because measurement protocols and data elements are more clearly specified for Montreal Process monitoring at the national level, it will be easier to identify potential opportunities for data sharing.

In addition to a desire to identify efficiencies in shared data, there is some desire in understanding how sustainability assessments at one scale can contribute to sustainability assessments at another scale. If we look at the results of the FMU-sustainability assessment as a whole, aggregating the results of one FMU assessment to another scale is not feasible. The emergent properties of a system make it unique. In understanding the relationship between initiatives at different scales, we found that the most value comes from narrative descriptions that describe the results in a context fashion. Narratives can be used to describe this "rich" picture.

Both national and FMU-scale initiatives also have a strong relationship with respect to the lessons learned about the process of monitoring. The growing literature on the Montreal Process C&I and the suite of indicators itself provided a valuable context and starting base for the LUCID Project. The process of preparing the 2003 National Report will highlight many new issues, ideas, data requirements, and data sources that will be useful for forests. From a process perspective, the LUCID forest teams learned a series of valuable lessons about systems approaches, the need for specificity, the balance between consistency and flexibility, reference values, and approaches and tools for analysis and synthesis that may be of benefit to the national initiative.

KEY FEATURES AND PRODUCTS OF FOREST MANAGEMENT UNIT SCALE SUSTAINABILITY MONITORING

The purpose of the LUCID Project was to determine if there was a core suite of C&I that might be generally applicable across the national forest system to assist in monitoring for sustainability at the FMU scale. Based on their experience, the LUCID forest teams concluded that a common systems-based framework—defined by 3 principles and 16 criteria—could be used across the range of test sites to provide a common organizing foundation and language to discuss the sustainability of ecological, social, and economic systems.

Systems Approach as a Common Guiding Framework

Chapters 2 & 7

The LUCID Project demonstrates that a systems approach provides an effective organizing framework to develop a sustainability-monitoring program for national forests. Specifically, the approach can accomplish the following:

- Lead to a richer and more integrated understanding of ecological, social, and economic systems;
- Help identify, define, and organize critical indicators and measures for monitoring;
- Serve as a conceptual basis for analysis and synthesis of monitoring data in order to assess the emergent properties of systems and the interrelationships between the ecological, social, and economic spheres; and
- Be applied consistently at the FMU scale and provide a consistent organizational approach to understanding, monitoring, and assessing sustainability. Adopting a consistent framework would have the added benefit of decreasing the inconsistencies among forests and improving understanding and transparency for the public.

A Core Suite of Indicators and Recommended Measures

Chapters 8 - 11

The eight national forests representing a range of different ecological, social, and economic conditions identified a relatively common set of principles, criteria, and indicators. There is a core suite of 58 indicators recommended for application across the national forest system for FMU-scale sustainability monitoring. However, some adaptation will be necessary to ensure that the indicators meet the full range of conditions on each national forest. The set of common indicators included in the final suite is the minimum set judged necessary to address the criterion. Some forests may want to enhance the core indicators with supplementary indicators focusing on specific system elements or functions of concern.

From the measure level through data elements and reference values, there is much less consistency; much more variability and flexibility are required. Three different kinds of measures were developed:

1. Recommended measures found to be relatively consistent from forest to forest. Where possible, these are based on standard, recognized Forest Service protocols or ideas.
2. Proxy measures as substitute measures for the recommended measures. While the recommended measure is the preferred or more common measure, the proxy measure presents an alternative means of obtaining the information.
3. Optional measures that forests might consider as supplemental to their list of measures and that are based on the issues of interest and concern for specific forests.

Corporate data systems and remotely sensed technologies provide a potential source of data to be used for FMU-scale sustainability monitoring. Some preliminary overlaps have been identified, but additional work and discussions are needed to ensure the best fit between corporate data sources and repositories and those required for FMU-scale sustainability monitoring.

Further development is needed including the following:

- Improved standardized measurement protocols to address questions at the FMU scale.
- Cooperation of various inventorying, monitoring, and data-management initiatives (e.g., corporate data collection and storage systems) to work together to develop an approach that can facilitate the supply and storage of information and data that are suited to a range of multiscaled questions.

Assessing Sustainability: Approaches to Analysis and Synthesis

Chapters 12 & 13

Ensuring that a monitoring program is useful involves the functions of synthesis, analysis, interpretation, and presentation so that monitoring data are converted to usable knowledge as part of the broader adaptive management process. Synthesis refers to the combination of ideas into a complex whole. In contrast, analysis refers to the abstract separation of a whole into its constituent parts for study. Our goal was to find tools and techniques to help us look not only at the components of systems (the parts) but also at the whole system.

The systems framework sets in place a common conceptual approach that can be used to frame analysis and synthesis of concepts. The goals of synthesis and analysis within the LUCID Project are to help managers and collaborators engage in a dialogue to make a *relative assessment* of sustainability rather than an absolute measure or *determination.*

At the most basic level, the analysis of the results of a sustainability-monitoring program involves interpretation of the results of the individual indicator assessments. A key weakness of an indicator-based analytical approach is the difficulty in highlighting and analyzing interrelationships between indicators. Individual indicator

Summary of the Key Products of the LUCID Project

Systems Approach

- Field application of systems theory
- Detailed systems descriptions
- Conceptual frameworks for each system
- Identification of areas for further development

Core Suite of C&I

- Common set of 3 principles and 16 criteria
- 58 recommended indicators
- Suite of recommended, proxy, and optional measures
- First thorough test of reference values as part of a C&I process

C&I Database

- The LUCID Resource Database containing detailed information assembled from the forest teams' experience on each principle, criterion, indicator, and measure
- An initial comparison of potential data sources from corporate data sets and identification of remote sensing potential
- Conceptual models for each indicator–measure element

Assessment Tools and Techniques

- Identification of key features for analytical tools and models
- Evaluation of software for analysis and synthesis and recommendations for improvement
- Base conceptual model for the suite of C&I within NetWeaver software

The Value and Process of Sustainability Monitoring

- Identification of ways that FMU-scale sustainability monitoring connects to forest management
- Revised process and key steps for FMU-scale sustainability monitoring
- Documented experiences of the forest teams supporting the process

Implementation and Recommendations

- Strategic implementation considerations and issues
- Tactical implementation considerations and issues
- Recommendations for further research

analysis does not capture the emergent properties of systems. Systems-based assessments work to synthesize the results of individual measure and indicator assessments within the framework of the structures and functions of systems. Synthesis is not an automatic function, however, but is a result of examining indicators within the systems context, synthesizing the evaluations of individual indicators based on these systems frameworks, and interdisciplinary discussions and dialogues about the state of systems.

Spatially based approaches to synthesizing individual indicator assessments are highly advantageous for resource management. Although models and other analytical tools may be based on mathematical algorithms, they were not determined to be the most appropriate results to report. Narrative approaches provide rich description of detail and can help synthesize across system components, reveal emergent properties, and facilitate the discussion of results across spatial scales. Where synthesis is the focus, the presentation of results should predominantly be narrative in nature supported by cautiously interpreted values.

LUCID participants found that analytical tools that are built on expert-systems were very valuable because they are object-oriented; can be organized and built to represent the full complexity of the interrelationships and emergent properties of systems; have the capacity to work with a range of reference values; and are capable of working with data from multiple spatial scales. Existing tools should be enhanced to include all of the most desirable features in a way that is compatible with USDA Forest Service corporate software. However, no one tool can provide all answers and there is a need for research to improve the science of assessing sustainability. While some standardization in analytical approaches and tools is useful, additional analytical tools and techniques will be required to fully analyze and synthesize sustainability monitoring information.

Further development is needed including the following:

- Enhancement of existing tools for analysis and synthesis to include all of the most desirable features in a way that is compatible with USDA Forest Service corporate software.
- Research and technical assistance to help resolve and enhance analytical tools and approaches.

The Process and Implementation of FMU Scale Sustainability Monitoring

Chapter 15

The steps involved in the process of developing and implementing a monitoring program for sustainability assessment at the FMU scale emerged as important as more tangible products such as a list of criteria and indicators. Based on the experiences of the LUCID forest teams a revised process was developed. Further development is needed including the following:

- Linkage to the new Planning Rule business requirements models.
- Establishment of a core technical assistance group that can build a community of practice about sustainability monitoring. This team can facilitate the implementation of FMU-scale sustainability monitoring creating efficiencies between forest efforts and improving consistency.
- Development and enhancement of tools that can serve as interactive repositories of monitoring components.
- Development of collaborative partnerships with outside specialists at the forest level.
- Establishment of a network of research and regional office specialists to support forest-level sustainability monitoring initiatives.
- Construction of a "lessons learned" database of case study experiences.

Implementation of FMU-scale sustainability monitoring relies on the following:

- Strong business requirements demonstrating the need and priority for such an initiative;
- Embedding sustainability monitoring within existing management processes;
- Reexamination of existing monitoring priorities;
- Elimination of redundancies;
- Forging strong connections with other related initiatives and programs; and
- More reliance on partnerships and effective collaboration to supplement the Forest Service's abilities.

Although there is much work and development still needed, based on the experience of the LUCID Project, the value and benefits from sustainability monitoring to on-the-ground management suggest we should begin and grow into the opportunity. A phased implementation process can start with a subset of national forests ready to engage the process.

CONCLUSIONS

The LUCID Project report documents a journey and a set of lessons learned by a group of dedicated national forest employees and partners. Like sustainability itself, although we shared a common goal we all had different understandings of how to make progress, how fast to go, and even sometimes, in what direction. Together, however, we began to develop a common language to discuss our values and our perspectives and we made significant steps towards the development of a set of tools and a process to help others monitor their progress in a quest for sustainability. There are some common themes that stand out as key messages and lessons learned:

- It is important to recognize that sustainability is a social concept and one that is incredibly valuable even though its definition is elusive.
- Developing a common language for sustainability is the way to help us tell the stories of sustainability that are unique to each forest and to each community.
- Sustainability can't be achieved by any one group of people, at one scale, and certainly not by the Forest Service acting alone. We need to act on multiple fronts, multiple scales, with our partners and get outside our boundaries, both physical and mental.
- In the face of uncertainty and multiple values, sustaining the contexts that sustain us, the fundamental systems, is the way to move forward.
- System-based approaches can help provide an organizing framework to understand how system components and functions work together. System frameworks provide an organizing tool to develop a monitoring program that turns data into knowledge by helping us select indicators and by providing a guide to analyze that information. But more importantly, a systems approach can be used to enrich our understanding of how the pieces and components of ecological, social, and economic systems work together—this has application far greater than a specific monitoring program.
- Sustainability is inherently a long-term concept, and monitoring is a process to take repeated measures over time. Sustainability assessment is not a one-shot deal. To be effective, we need to ensure that sustainability monitoring continues in the long-run and we need to track the direction and rate of change of our progress over time.
- Sustainability assessments are relative not deterministic in nature and should involve people in a discussion about sustainability.
- Sustainability monitoring is an iterative process. The development of indicators and an approach to monitoring was built on the experience of others, and others after us will propose many good revisions and changes. Future iterations are required and necessary, but we should not be paralyzed into a state of inaction because we know we haven't got everything right yet. Start now. Refine as we learn.
- Tools, models, and computer programs will never be as powerful at integrating as the human mind: particularly when we collaborate with our partners. Use tools and models to help us; but, remember the value in discussing together how and why things are working the way they are.
- All results are contextual and without sufficient detail and interpretation have little meaning. Techniques that explain the context, the interrelationships, and the uncertainties are the most useful in building understanding.
- The complementary action to managing and monitoring for sustainability is living sustainability. Personal responsibility for sustainability rests with each employee, each resident, and each forest visitor.

The establishment and implementation of a sustainability monitoring program at the forest management unit scale represents one approach to sustaining the systems, the contexts, that sustain us. The systems approach represents the way to sustain our diverse perspectives on the things that we individually value about healthy lands, healthy communities, and healthy economies.

SECTION 1:
BACKGROUND AND CONTEXT

CHAPTER 1. THE PATH TO SUSTAINABILITY

Introduces the concept of sustainability and the criteria and indicators approach to sustainability monitoring. Outlines the purpose, objectives and initial expectations of the LUCID Project.

CHAPTER 2. A SYSTEMS APPROACH TO SUSTAINABILITY MONITORING

Discusses the adaptation of the systems framework through the LUCID Project and introduces basic concepts of systems thinking. Key advantages of the systems framework are highlighted and contrasted with other possible frameworks.

CHAPTER 3. SCALE AND SUSTAINABILITY MONITORING

Introduces the importance of scale, both spatial and temporal, in the design of monitoring programs and discusses the nature of systems with respect to scale. The approach to defining the forest management unit (FMU) scale in the LUCID Project and the implications of working at this scale are discussed.

Chapter 1.

The Path to Sustainability

Perspectives on Sustainability 4

- *Discusses various perspectives, objectives, and aspects of sustainability that frame the design of the monitoring program.*

Sustainability Monitoring 10

- *Introduces the criteria and indicator approach to monitoring within a systems approach.*

The LUCID Project 14

- *Outlines the project purpose and objective and provides a brief overview of the LUCID Project.*

The LUCID Experience: Benefits from FMU-Scale Sustainability Monitoring 14

- *Describes the initial rationale for participation in the project and summarizes the core benefits from a monitoring program for sustainability from a desire to improve management and monitoring systems to a goal of improving collaboration.*

Overview of the Report 18

- *Provides a guide to the organization of the report.*

Every day throughout the United States, and indeed the world, people seek to find places to sustain their spirit like the imagined environment on the cover of the report. A place where a fisher can find the quiet solitude of a mountain lake and an abundant catch of trout. Where a group of friends can escape from the city for the day to mountain bike on a rugged rocky trail. A place with clear flowing streams and healthy meadows where the rancher takes his cattle each spring. A place where a Native elder can—within her traditional territory—pick huckleberries and gather bear grass for her family. This is the place where the late afternoon sun finds the ranger on her way to a community meeting on the prescribed fire plans stopping to help a crew of Scouts unload a wheelbarrow of gravel for the hiking trail. A place where fathers, sons, and uncles can revisit in time-honored tradition the hunting camp and the quest for a mythical encounter with a buck. This is the place—the distant vista of velvet green forests and dramatic mountain peaks—that is the "million-dollar-view" the realtor describes to the couple apartment hunting in the city. It is an open forest of ponderosa pine, a forest of towering Douglas-fir, or a forest of quaking aspen where morning finds a crew of loggers with saws and cables on their shoulders and a careful set of eyes marking the fall lines and the reserve for the osprey nest. This place provides the fine dark cherry for the cabinetmaker, the clear strong pine boards for the builder, and—in a hundred different ways—groceries for the table. This place is honored by decades of photos in the family album as the best place to find the perfect Christmas tree.

No hypothetical place, this description is a collage of genuine images from our national forests and grassland. It portrays the collective journey we have undertaken to find a way to live harmoniously with each other and with our environment. The journey is a quest for sustainability.

Sustainability is not a thing but a social value or an ideal, like justice, honor, or truth. The term expresses the human desire for an environment that can provide our needs now and into the future across many generations; but what the term implicitly conveys and what it explicitly means are not necessarily the same. Finding a specific definition of sustainability on which we can all agree is difficult—some would say it is a pointless quest—because it is about values and values vary between groups and over time. Paradoxically, the things we decide to sustain have value only because we do value them. The sustainability quest is about deciding what to sustain, for whom, for how long, how (see for example Clawson 1975, Romm 1994, Gregersen et al. 1998) and at what cost (see for example Clawson 1975, Tainter, 2001). Yet with all its uncertainties and critics, sustainability as an idea has widespread appeal and is the term that has emerged to encapsulate our collective thinking.

"Definitions of sustainable forest depend on what people want...Sustainable forest has no meaning until the what-where-when-how-who of the forest, the value perspective, is identified." (Romm 1994)

It represents the beginning of a dialogue and the development of a new and shared vocabulary.

Common to most expressions of sustainability are the interdependencies of ecological, social, and economic systems regarding both present and future generations. Sustaining the basic contexts for the systems that sustain us is the bottom line (Allen and Hoekstra 1994).

Nowhere has the struggle for sustainability and the development of the dialogue been more focused than in relation to forests. The sustainability, first of tropical and then temperate forests, has brought the larger dialogue about sustainability into our backyards. This

"From the human perspective we see the ecosystem as having a purpose. That purpose is to support and sustain human welfare as defined by the values and preferences we hold. But, because human life depends on the condition of the ecosystem as a whole, the higher purpose is to sustain the ecosystem such that it is capable of sustaining human life, and not only human life, but quality human life and hope of continued improvement into the future. This purpose lifts us out of the ecosystem, so to speak, into a role of stewardship. Because we have emerged as the species in control (some would say 'out of control') but capable of reasoned action and self control, we must accept the responsibility to manage the behavior of the whole ecosystem by managing ourselves within the system as well as managing and nurturing the system with which we interact." (Brown and Peterson 1994)

sustainability dialogue has cascaded into many different areas of our lives, from sustaining big industries to sustaining small farms. The time frame for such endeavors of renewal typically span just a few years of a single person's life; but the challenge of renewing forests exceeds a single person's lifetime and extends into the lifetimes of great, great grandchildren. How quickly and thoroughly a forest renews itself depends on whether people assume an active or passive role in the renewal process.

Within the United States many agencies, industries, organizations, and citizens have engaged in the quest for sustainability through various initiatives (see Appendix 1). This report presents the results of one initiative: a USDA Forest Service project for monitoring for sustainability at the local, or forest management unit (FMU), scale. Engaging in a project to monitor sustainability first requires a discussion of the nature of sustainability.

Perspectives on Sustainability

Both the academic and popular literature are filled with discussions about sustainability, and this body of literature reveals diverse opinions about what sustainability is and is not. Because the public researchers and managers, scientists and administrators do not all embrace a single shared concept of sustainability, some people argue whether it even really exists as an achievable endeavor beyond being an idea on paper. The sustainability discussion represents a relatively new interface between science and management, so exploring the range of perspectives and their common themes is essential for understanding the context of monitoring sustainability.

Although the term *sustainability* has been around for longer, the most common conception of it, sustainable development, was popularized through the 1987 publication of *Our Common Future*, the report of the Bruntland Commission (WCED 1987). The Bruntland Commission defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED 1987).

Despite broad use, this definition has been criticized as "so vague as to be consistent with almost any form of action or inaction" (Pearce et al. 1993) and essentially totemic in nature. In fact this and other definitions of sustainable development have engaged many people in circular debates that conclude the idea is so vague and controversial that the term should be abandoned. Others however, conclude that it is indeed a value-laden concept but that guidance can be taken from these types of general definitions.

> *"Defining sustainability and sustainable forestry is troublesome. Definitions abound, but there is little consensus. Some will argue that because sustainability cannot be readily and specifically defined, it is of little value. We suggest that there are many useful ambiguous terms in our society (e.g., "justice" and "democracy") and in our profession (e.g., "multiple use," "forest health," and "ecosystem"). Engaging in the process of developing a common understanding of these terms is one of the things that define us as a profession."*
> *(Floyd et al. 2001)*

Writing for the Center for International Forestry Research (CIFOR), Colfer et al. (1995) modified the Bruntland definition to more specifically address forests; "Sustainable forest management aims to meet the needs of the present without compromising the ability of future generations to meet their own needs. Two conditions indicate sustainability for this definition: (1) ecosystem integrity is ensured/ maintained; (2) well-being of people is maintained or enhanced."

Prabhu and his colleagues (1999) incorporated these indicators by defining sustainable forestry as "a set of objectives, activities, and outcomes consistent with maintaining or improving the forest's ecological integrity and contributing to people's well-being now and in the future."

Sustaining Outputs or Contexts

Some people feel that the Bruntland and similar definitions focus too much on the material aspects of well-being—the production of goods that are often equated with human needs. Alternatively, these critics reason that a useful definition should focus on the sustainability of the systems that support production. Tainter (2001) and Allen et al. (n.d.) propose that sustainability entails "maintaining or fostering the development of the systemic contexts that produce the goods, services, and amenities that people need or value, at an acceptable cost, for as long as they are needed or valued."

Sustainability as a State or a Process

In pure systems theory, a system is either sustainable or it is not (Allen and Hoekstra 1994). If some component or function within the system is undermined without intervention, the system will collapse. In the purist sense, then, sustainability is a state and expressions such as *almost sustainable* or *the degree of sustainability* are false. Most people recognize, however, that defining absolute sustainability (e.g., knowing all the components and interactions and the critical thresholds for each) is illusory, arrogant, unachievable, or some combination of these.

> *"Sustainability is not a goal, not a condition likely to be attained on earth as we know it." (Lee 1993)*

Many people view sustainability as that ideal goal or state towards which we strive (Brown and Peterson 1994); and, consequently, the idea of sustainability as a process has become commonplace. The Bruntland Commission report, for example, stated that "sustainable development is not a fixed state of harmony, but rather a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional change are made consistent with future as well as present needs" (WCED 1987).

What many refer to as the "sustainability process" summarizes a set of behaviors or actions that they believe will help them achieve a state of sustainability, whether they mean it as an absolute state or as a range of conditions. Throughout this report, for example, we refer to the importance of process in our sustainability project. In this sense we describe our values for sustainability and the particular approaches, tools, and steps that became the process most useful for understanding and monitoring sustainability.

Sustainability or Sustained Yield?

The terms *sustainability* and *sustained yield* share both a core word and a core idea, but they are not the same. Any meaningful discussion of this subject must unequivocally distinguish them. Legislated mandates, particularly the Multiple-Use Sustained-Yield Act (1960), have defined and periodically redefined sustained yield. Originally, it meant "the amount of wood that a forest can continually produce at a given intensity of management" (Helms 1998). This narrow meaning has been expanded through time to include more than just timber, but the expanded meaning still emphasizes the supply of resources and commodities as discrete elements in space and time.

As Holling et al. note (1998), the time horizon may be expressed ecologically as "in perpetuity." However, commerce actually governs the time horizon when living resources reproduce slowly (and therefore replenish slowly) or when long-term ecological values are discounted so greatly that no legitimate value exists. Under this scenario it is best to deplete the resource quickly and reinvest money. The result is sequential exploitation of stocks.

Sustained yield is focused on quantities of resource outputs from a land system. These quantities of resources are considered individually and at times efforts are made to "integrate" the resource outputs in bundles. The individual resource outputs are generally accrued from multiple time and space scales. The difficulty of interpreting how land management activities generated the sustained yield of more than one resource output at a time has created very large linear optimization models. The fundamental problem with the sustained yield perspective is that it fails to recognize that management activities influence joint-production land systems that constantly provide soil, water, air, plant, and animal material—portions of which humans use as resources. The focus of sustainability should be on the joint production system. Investment in targeted management activities can alter (increase or decrease) the resource outputs of a joint-production land system. Focus on the joint-production land system and there is no need for post anti-integration. Land systems are by definition integrated joint production entities.

What Scale is Sustainable?

Some people can perceive sustainability only on a scale as large as a continent, but systems exist and are viewed at different scales with resources and their attendant values moving between them. To be effective, sustainability initiatives must address issues of space and time and include community, forest, regional, continental, and intercontinental scales. Specifying the spatial scale helps identify specific values and the systems that produce those values, both of which must be accomplished so we can understand which systems are important to sustain.

Sustainability of What, Where, for Whom, for How Long, and at What Cost?

Because sustainability lacks a single clear definition and specific conditions, discussions about it can ramble and ultimately fail to produce meaningful results. To achieve meaningful results, discussions must resolve the basic questions of sustain what, sustain where, sustain for whom, sustain for how long, and sustain at what cost (see for example Clawson 1975, Romm 1994, Gregersen et al. 1998, Tainter, 2001).

The choice of what to sustain and where to sustain it is critical to bounding the discussion of sustainability. Indeed, much of the debate about these questions revolves around how the term *sustainability* is used as a part of speech (see for example Shearman 1990, McCool and Haynes 1995). Sustainability the concept, used as a noun, is easy to support and endorse; but the question of what to sustain converts it to an adjective that spawns different opinions.

The temporal component of sustainability is particularly important because short-term outcomes may clash with long-term outcomes (see Chapter 8), the conflict of which may ultimately preclude one or the other. Resolving the conflict entails choice, and choosing between incompatible outcomes inevitably creates the perception of winners and losers; and no one, no user group of our natural resources, accepts the losing end of such a choice. A vital aspect of the temporal component involves establishing the proper perspective of time. Sustainability is not about how long a certain resource activity will last, but rather it is about how long that same activity can be extended productively. A rhetorical expression of the temporal component of sustainability might be expressed this way: people needed wood yesterday; we need wood today; and people will need wood tomorrow. People of the past got their wood; we are producing our wood today; will people have wood available to them tomorrow? Ergo, addressing resource equity

Sustainability of What

The following examples illustrate how the emphasis shifts between the forest itself and the human endeavor to manipulate the forest.

- Sustainable Forestry—Sustainable forestry from a biocentric perspective is defined as "the act of managing forests to provide the necessities of life" (Coufal 1999).
- Sustainable Forestry/Sustainable Forest Management—"[t]he practice of meeting the forest resource needs and values of the present without compromising the similar capability of future generations… involves practicing a land stewardship ethic that integrates the reforestation, management, growing, nurturing, and harvesting of trees for useful products with the conservation of soil, air and water quality, wildlife and fish habitat and aesthetics" (UNCED 1992).
- Sustainable management involves— "[t]he stewardship and use of forests and forest lands in a way, and at a rate, that maintains their biodiversity, productivity, regeneration capacity, vitality, and potential to fulfill, now and in the future, relevant ecological, economic and social functions at local, national, and global scales, and does not cause damage to other ecosystems" (Ministerial Conference on the Protection of Forests in Europe, Helsinki 1993).
- Sustainable Forest—"The capacity of forests, ranging from stands to ecoregions, to maintain their health, productivity, diversity, and overall integrity, in the long run, in the context of human activity and use" (Helms 1998).

within and among human generations is a common component of most sustainability definitions. Consequently, the question of sustainability for whom involves careful consideration of issues of intra- and intergenerational equity.

While some people define sustainability as a narrow financial concept and ask simply whether a venture such as managing a national forests is financially viable, the broader question of cost entails other critical issues. Built systems, such as the closed system of the international space station, are sustainable if enough energy (measured by the dollar cost of food, water, oxygen, and electricity) is continually added to the system. Natural systems are open systems, many of which may exist in different conditions, or states. They can likewise be sustained if enough energy is added to them, but open systems are not as simple as closed systems because they interconnect and influence each other both directly and indirectly. An important, although often ignored, element in deciding what state of the system to sustain is the question of cost. The critical issues of the cost question are who pays, who benefits, can the cost be sustained, and what is the real cost (short-term and long-term) if the system is not sustained? Such cost analysis is an integral part of the sustainability dialogue.

Ecological Perspectives on Sustainability

Some people have defined sustainability from a purely ecological perspective, stating that sustainability is more akin to the concepts of ecological or biological integrity. In this context, the human role in the natural system is encapsulated by vague and relatively meaningless statements to the effect "humans are part of ecosystems." In certain contexts this implicitly attempts to legitimize anything that anyone wants to do with natural resources without regard to consequences. And yet, humans are living creatures that do connect with natural systems. Finding a fit for the nonbiological aspects of human systems (e.g., societies and economies) within this perspective is challenging.

A perspective of ecological empiricism states that of the components of sustainability (for example ecological, economic, and social), the ecological dimension is paramount. Treating socioeconomic systems as stressors and intrusions on the natural world, as if human systems were completely unnatural, is often the outcome. This perspective can be misleading since there are important multidirectional feedbacks between socioeconomic systems and ecological systems. Perceiving the interrelationships as unidirectional can be problematic.

The preeminence of the ecological dimension can be interpreted more moderately by simply recognizing that human systems are fundamentally based on the biological limits and hence, sustainability, of the ecological system. Some people, however, find that the idea of ecological dominance results in an uncertain role for humans within the environment.

The idea of a minimum-versus-maximum approach to sustainability provides another ecological perspective. Jacobs (1991) states that "sustainability means that the environment should be protected in such a condition and to such a degree that environmental capacities (the ability of the environment to perform its various functions) are maintained over time: at least at scales sufficient to avoid future catastrophe and at most at scales that give future generations the opportunity to enjoy an equal measure of environmental consumption." Hardoy et al. (1992) and others state that this maximal sustainability perspective may also require improvements or restoration in environmental quality if the current environment is already degraded.

Socioeconomic Perspectives on Sustainability

Economic definitions and discussions of sustainability raise a variety of different points that have contributed to the sustainability dialogue. Central to these is the focus on maintaining natural capital. Natural capital refers to the stock of ecological resources including water, soil, vegetation, and wildlife, plus, in the broadest

> *"Should one be focusing on the preservation or enhancement of natural resources or should one be looking at the entire mix of resources (the environment, human knowledge, man-made capital, etc.) that comprise what is called social capital?"*
> *(Loucks 1997)*

definitions, the capacity of the environment to assimilate pollutants. The means of achieving sustainability is to maintain the stock of natural capital and to live off the "interest," or productive excess, and ideally to invest enough to increase the available surplus.

If the focus of sustainability is on maintaining natural capital, then nonrenewable resources present a challenge. From one perspective, there is no sustainable harvest rate of nonrenewable resources; and therefore, they must be preserved. Discussions about sustaining nonrenewable resources are really just attempts to co-opt a concept to make harvesting them more acceptable. More legitimately, nonrenewable resources can be consumed if there is some acceptable form of substitution or if future generations are compensated in some way.

The broader issue of substitution of capital is also central to economic discussions of sustainability. Some economists view all capital (natural, human, built) as substitutable and suggest that the most efficient thing to do and therefore the wisest (from this perspective efficiency is central) is to convert inefficient natural capital and substitute it with much more efficient forms of capital (e.g., built capital).

Some participants in the sustainability dialogue have contrasted many of these ideas and differing perspectives about capital and substitutability in a discussion of what is frequently termed "weak" versus "strong" sustainability (see, for example, Pearce and Atkinson 1993). Weak sustainability advocates maintaining as much of the status quo as possible and stresses current generations. This perspective

Sustainability or Desirability

Through the LUCID Project, individuals and teams had a variety of discussions on the meaning of *sustainability*. Although at times these discussions seemed circular and unwieldy, they revealed the value in the process of developing a metaphor and defining the language of sustainability together. One of the most intriguing debates concerned the question: Is there a difference between *sustainability* and *desirability?*

- **Sustainability is Based on Values and Values are Desires.** What we choose to sustain is based on what we value: our needs and desires. Some discussions of sustainability suggest that the focus should be limited only to basic human (and by extension, ecosystem) needs; but defining which are needs and which are desires is fuzzy. When we think of sustaining ecological systems, is there a distinction between needs and desires? Do ecological systems need certain things, certain conditions to be sustained, with others being optional? Posing the question of whether something is desirable or sustainable makes it seem as if there is a most preferred state, reference value, or threshold. It may also mean that some of the things we desire are not necessary to sustain us; but where are the boundaries, and who is going to decide which components are frivolous? The challenge of sustainability is the challenge of understanding what we value and then determining whether we can sustain all the things we value.
- **Desired Future Conditions.** Is sustainability a construct in absence of human values? Are there components and absolute thresholds for those components that if we could identify them would be those things we need in order to ensure sustainability? Although there are many system components, ecological and socioeconomic, that we might identify as absolutely fundamental, identifying which are critical and what their absolute thresholds are is beyond science. The reality is that sustainability is about finding our place, the human place, in the world. Making the link between what we value and the desired future condition, the target, for that thing we value is key. For example, based on what we value we may desire to retain native species diversity. Through research we may be able to identify some absolute thresholds for minimum population size or habitat requirements needed to retain a desired species. These desired future conditions, whether more absolute thresholds derived through research or, more frequently, professional and stakeholder assessments of what is possible, are based on values.
- **Short-Term vs. Long-Term Outcomes.** Sustainability and desirability may also be viewed as the distinction between short-term and long-term outcomes. Examining the feasibility of sustaining a critical system component from both an intra- and intergenerational perspective (or short-term versus long-term) may be one way of conceptualizing the desirability-versus-sustainability discussion. Perhaps things that are desirable, but not sustainable, are those that are only short-term in nature while things that are sustainable are those that meet long-term, intergenerational needs (see also Chapter 8).

emphasizes "nondeclining utility, nondeclining consumption, and the nondeclining value of total investments in the manufactured, human, and natural capital stocks" (Toman et al. 1998). Strong sustainability emphasizes intergenerational needs and places value in the changes in certain critical stocks of natural capital based on the assumption that there are certain types and levels of irreplaceable capital. Strong sustainability establishes these criteria *a priori* and uses a range of policy mechanisms (e.g., emission limits or emission trading credits) to seek "the most effective and least costly ways to achieve the goals" (Toman et al. 1998).

The discussion of welfare and intra- and intergenerational equity is also a critical contribution from socioeconomic perspectives. Consistent with the notion of maintaining natural capital, intergenerational equity "requires that each generation manage its resources in ways to ensure that future generations can meet their demands for goods and services, at economic and environmental costs consistent with maintaining or even increasing per capita welfare through time" (Loucks 1997). The concepts of fairness and equity in the distribution of costs and benefits of sustainability, although often difficult to measure, are seminal contributions to the sustainability dialogue.

Interpretations of social sustainability are often quite broad but include as essential components such things as meeting basic human needs, personal growth and development, maintaining physical and mental health, equity, community resilience, and involvement in decisionmaking (Richardson 1994, British Columbia Round Table 1993).

In contrast, Tainter (2001) posits that "[c]onceptualizing sustainability in terms of human well-being potentially opens Pandora's box." Such concepts, Tainter writes, may be desirable goals of human society but "may appear to some observers to have little to do with sustainability." He suggests that the challenges are twofold and require first to identify social goals related to sustainability and those that are unrelated and second to conduct an assessment (e.g., historical analysis) to show that a particular aspect of well-being has been missing in societies that are unsustainable. In this context he concludes, for example, that the health of people in forest-dependent communities, while laudable, is not a goal of sustainability. These ideas, while raising the difficulties of identifying the critical aspects of social sustainability in forested environments, contrast sharply with other writing on sustainability and social well-being (see for example Colfer et al. 1999 and Colfer et al. 2001) and those espoused nationally and internationally in communities forums on sustainability[1].

Another perspective of social sustainability (Hardoy et al. 1992) focuses on perpetuating existing institutions and customary behaviors and relations in their current state. However, others believe this conception of sustainability may conflict with ecological sustainability and may require some fundamental changes to institutions, traditional uses, and current social values (e.g., kinds of employment) in order to be compatible.

The issue of "who counts" is germane to many social perspectives on sustainability and in certain aspects the issue is pivotal. Colfer et al. (1999) argue for the importance of local people in involvement, decision-making, and sustainable management. The debate about balancing local with national interests, particularly in the case of public lands, is a discussion about power and is in many situations the central theme in sustainability.

Defining Sustainability Through an Interdisciplinary Process

Throughout the LUCID Project, we have described sustainability as an emerging value that results from the interaction of ecological, social, and economic systems. Many specialists are working on developing and understanding the sustainability concept, but everyone has a point of view about what sustainability is. Disciplinary conceptions of the term, though useful, will by nature be incomplete because people will define sustainability with discipline-specific vocabulary (Allen et al. 1994). Sustainability "calls for broader disciplinary integration and subtler conceptualization than are offered by current efforts" (Allen et al. 1994). Creating a process for dialogue and the development of a shared vocabulary are critical to moving sustainability from semantic debate to application.

---

[1] The continued work of the 7th American Forest Congress Communities Committee, through their participation with the Roundtable on Sustainable Forests, illustrates this. www.sustainableforests.net. (See also Maclaren et al. 1996, Hart 1999).

One of the primary approaches to addressing the sustainability question has been a focus on monitoring to aid in assessing sustainability and to monitor change towards collaboratively developed desired outcomes. Within the LUCID Project we made a conscious decision that because of the nature of values and the complexity of the concept of sustainability we would not attempt to provide a specific, uniform definition of sustainability. Instead, we would focus our attention on the notion that sustainability would be best achieved by sustaining the contexts and that a monitoring program would focus on identifying those critical aspects of systems.

We also decided that to address the range of possible perspectives on what sustainability is an interdisciplinary and collaborative approach would be critical to designing, implementing, and interpreting the results of sustainability monitoring. Clearly it is quite possible that even with a focus on monitoring the sustainability of systems that what people value may not result in a sustainable system. However, the intent of the monitoring program is to provide feedback to inform that discussion.

SUSTAINABILITY MONITORING

If our goal is sustainability, how well are we doing? Monitoring has emerged as one of the primary management responses to the sustainability challenge and it helps us understand the condition of systems and what we value as sustainable. Monitoring has focused on developing the tools necessary to gauge where we are relative to where we want to be. In other words, how well are we doing?

> *"We are working under the assumption that better information on the ecosystem (which includes human social systems) will lead to management decisions that have a better chance of being sustainable. If we assume all management (that is, decisions in the generic sense) is a choice between alternative futures, the value of monitoring is to provide information on the direction and future state of the system. Simply put, for any given decision, where is the system likely to go?" (Woodley et al. 2000)*

Monitoring is the "repeated observation, through time, of selected objects and values in the ecosystem to determine the state of the system" (Clayoquot Sound Scientific Panel 1995). In the context of sustainable ecosystem management, a monitoring program establishes a set of markers that help determine whether the ecosystem is being managed in a sustainable fashion. Specifically, monitoring may be useful to accomplish the following:

- Build a base of understanding about the system by revealing patterns and trends;
- Establish benchmarks of the current state of the system for comparison to desired future conditions;
- Detect change in the system and serve as an early warning of change;
- Evaluate the effectiveness of programs and measure progress towards goals;
- Identify changes in baseline conditions for key indicators that result from management actions, including restoration activities;
- Support planning and management decisions through the identification of key issues and trends;
- Communicate about the state of the environment; and
- Serve as an accountability mechanism for the public, managers, governments, and international communities.

Monitoring and the Adaptive Management Cycle

In adaptive management managers systematically and rigorously learn from specific actions so that they can accommodate change. It is not simply hindsight but a conscious treatment of management as a set of experimental actions that through monitoring can be adjusted to improve the results of management (see Figure 1).

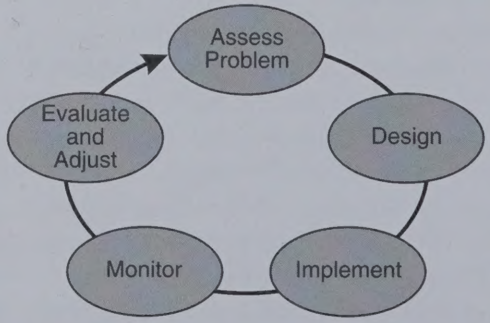


Figure 1. An Application Cycle for Adaptive Management

Creating a Monitoring Program that Manager's Can Support

Monitoring is one of the many activities that assist resource managers, yet building and sustaining support for comprehensive monitoring programs are still very difficult. Monitoring is often viewed as a costly incidental activity that takes scarce resources away from actually doing things.

Frequently cited primary reasons for failure of monitoring programs are as follows:

- The costs of monitoring are perceived by managers and the public to be prohibitively high, so there is reluctance to commit to implementation.
- Monitoring programs are often developed in absence of science.
- Monitoring programs try to measure too many attributes that are not linked to a specific purpose or objective.
- Indicators often focus on the status of a species rather than on what ecosystem condition the species' presence indicates.
- There is little visible logic to support the selection of indicators, and they too often appear to be programs based only on the interests of individuals.
- Monitoring elements are not visibly related to one another.
- There are no institutionalized connections between monitoring and decision processes.
- Failure to identify thresholds, margins of concerns, or trigger points prevent management attention and action.

Numerous authors suggest that to gain institutional support the monitoring program must do the following:

- Clearly state the management goals and objectives for monitoring and discuss how information about the status of the systems/resources is needed for decisionmaking;
- Explain why the monitoring program has value, what information it will provide, and how interpretation of the information can lead to more informed management;
- Identify factors that can compromise management goals and the state of the system, perhaps by modeling the system to show how it can be affected by external stressors or issues;
- Describe the rationale or logic for selection of indicators;
- Build in flexibility to adapt to the unique circumstances of any given situation but allow enough consistency so that there is a shared common language between managers and collaborators;
- Link monitoring programs to effective data management systems and quality assurance programs; and
- Connect monitoring to decision-making showing what change should trigger a management response.

(Natural Research Council 2000, Palmer and Mulder 1997)

Consequently, monitoring is not independent from the larger management process. "Good management requires good information," and a monitoring program can provide this when it is "structured into the process of management, well designed and executed" (Landres 1995). Monitoring becomes the core, the essential feedback loop, of managing for sustainability.

The Focus on Indicators

Selecting indicators represents the critical first step in developing a monitoring program. Indicators supply small bits of information that reflect the status of the larger system. Indicators help "quantify and simplify large amounts of information, thereby making it more useful for the audience" (United States EPA 1994). They come in various shapes and sizes and are used for diverse purposes from description to prediction. No one set of indicators universally applies to all sustainability monitoring. A unique suite of indicators must be selected for each monitoring situation but with the intent that they each reveal information about interactions of the social, economic, or ecological systems at a specific scale. The identification and measurement of the best suite of indicators is a work in progress.

Indicators are not generic; and though valuable sources for developing indicators exist, indicators must be chosen to represent systems at the target scale of interest and be adapted and tested in an appropriate context. Indicators are just that: indicators. They *indicate* what condition the system is in but they *are not* the system. Even if we monitored all the indicators that we would like, the result would still be as incomplete as our definition of systems and our imperfect knowledge of these systems. Indicators are signs on the path to sustainability, and some signs provide more information than others.

No system can be monitored with just one or even a few indicators. Individually, indicators provide valuable data; but the collective information from all the indicators is what informs us about the state of the system. Therefore, indicators must be interpreted as a package. To select indicators, monitoring collaborators must agree both to the purpose for the monitoring program and to the scale of interest. Agreement is important because different kinds of monitoring lead to the selection of different kinds of indicators.

Criteria and Indicators for Sustainability

Criteria and indicators (C&I) are a framework designed to provide a common understanding of what is meant by sustainable forest management and to structure the monitoring process. Given the abstract nature of the sustainability concept, this hierarchical framework (see Chapter 6) is intended to elucidate, step-by-step in a logical way, the goal of sustainable management. The C&I framework expresses the goal as parameters that can be monitored and assessed. Numerous national governments, international declarations, forest management units, and forest certifying bodies use the C&I approach to structure monitoring efforts (see Chapter 6).

> *"By moving us beyond vague—but important—discussions about sustainability in the abstract, indicators are already helping us not only to establish numerical goals and analyze trends but also to explore the full implications of this concept."*
>
> *(Farrell 1998)*

Origins of C&I

The 1992 United Nations Conference on Environment and Development met in Rio de Janeiro where participants reaffirmed a declaration adopted in Stockholm in 1972. The objective of the Rio conference was to work towards international agreements, respecting the interests of all people and protecting the integrity of the global environment and development system.

Agenda 21 (see Appendix 2), the report arising from the Rio Conference, called for a set of legally nonbinding principles for management, conservation, and sustainable development for all kinds of forests and supported the need for developing monitoring systems "in order to educate the public and make informed management decisions."

One of the first groups to take up this challenge evolved from a seminar in Montreal in 1993. The International Seminar of Experts on Sustainable Development of Boreal and Temperate Forests focused specifically on the development of criteria and indicators for the sustainable management of temperate and boreal forests. As a result of this initiative, the Working Group on Criteria and Indicators for the Conservation and Sustainable Management of Temperate and Boreal Forests (referred to as the "Montreal Process") formed in Geneva in 1994. The Montreal Process Working Group was formed to advance the development of internationally accepted C&I for temperate and boreal forests at the national scale. Membership currently stands at 12 countries, and among them these countries contain more than 90 percent of the world's temperate and boreal forests. In February of 1995, the working group countries endorsed a comprehensive set of national-scale C&I in Santiago, Chile (Santiago Declaration: see Appendix 3) for conservation and sustainable management applications in their respective countries.

The Montreal Process was intended to provide a common understanding of what is meant by sustainable forest management and to provide a common framework for describing, assessing, and evaluating a country's progress toward sustainability. The Montreal Process C&I establish both an international reference for policymakers who form national policies and a basis for international cooperation. The United States in 1995, through the lead of the Forest Service, agreed to use the Montreal Process C&I to measure national progress in achieving the goals of sustainable forest management. The first

United States report on the Montreal Process was published in 1997 and the second is scheduled for 2003 (United States First Approximation Report). National and international governmental processes in other locations have resulted in similar C&I initiatives for other forest systems including the Helsinki Process for many panEuropean countries (see Figure 2).

Although much of the initial focus on C&I came from the need to report both nationally and internationally on sustainable forest management, there was growing realization that sustainability issues are multiscaled and that the national goals of sustainability rest, in large part, on the actions that are carried out at the local scale. The need for forest-scale C&I initiatives arose not because of the imposition of top-down needs but because of the recognition that local-unit monitoring and reporting were essential to understanding and achieving sustainability at the FMU scale.

The Center for International Forestry Research (CIFOR), a part of the Consultative Group on International Agricultural Research, is the pioneering organization in the field of local-unit indicators and has developed and tested C&I at the "forest management unit" (FMU), or local scale.

Forest Certification

Certifying sustainable forest management and sustainable forest products represents a complementary tool to address the issues of sustainability. Whereas C&I are neutral assessment tools that define a given monitoring initiative and develop "benchmarks to measure and report progress towards sustainability" (FAO 2001b), certification is a market-based instrument "designed to document and reward sustainable forest management practices, and assure consumers of forest products that their purchase comes from a well-managed forest" (Washburn and Block 2001).

Certification is generally understood to be a voluntary process that includes "independent verification" (Society of American Foresters 1999) of conformity to standards, typically by an independent third party. Certification and C&I share much of the same evolutionary history; but despite their common attributes, they represent two different responses to the challenge of sustainability. Although this project focuses on C&I, the similarities, differences, and relationships between the two are discussed in more detail in Chapter 14.

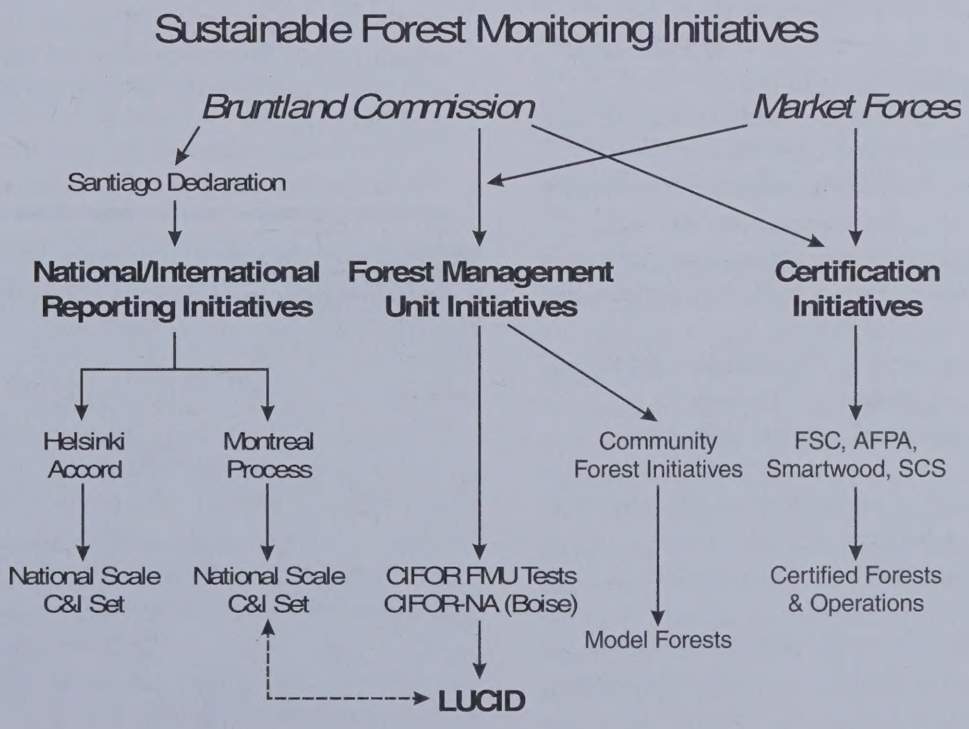

Sustainable Forest Monitoring Initiatives
Bruntland Commission
Market Forces
Santiago Declaration
National/International Reporting Initiatives
Forest Management Unit Initiatives
Certification Initiatives
Helsinki Accord
Montreal Process
Community Forest Initiatives
FSC, AFPA, Smartwood, SCS
National Scale C&I Set
National Scale C&I Set
CIFOR FMU Tests CIFOR-NA (Boise)
Model Forests
Certified Forests & Operations
LUCID

Figure 2. International Forest Sustainability Effort

THE LUCID PROJECT

As a first step towards using local-unit C&I in North America, the Forest Service and CIFOR tested FMU-scale C&I near Boise, Idaho in 1998. Government, industry, and nongovernmental organizations from Canada, Mexico, and the United States participated. The CIFOR-NA test refined and adapted the global CIFOR C&I set to the ecological, social, and economic conditions of North America. An important outcome of the CIFOR-NA test was recognition that local-scale C&I can provide the information needed for sustainable management of our national forests.

Based on this preliminary test, the Forest Service Local Unit Criteria and Indicator Development (LUCID) test was chartered by the Chief following the 1998 North American Forestry Commission meeting. The intent of the LUCID Project was to work with personnel at six national forests and thereby expand the science-based evaluation to develop a forest-scale monitoring program for sustainable ecological, social, and economic systems.

Project Objectives

The purpose of LUCID was to conduct a pilot test that would appraise the feasibility of monitoring sustainable systems at the forest management unit scale. The intent of FMU-scale sustainability monitoring is to provide forest managers and collaborators with feedback that can be used to improve Forest Land Management Plans; to enhance collaboration between national forests and other governmental agencies; and to relate forest plan outcomes with regional and national C&I trends. Five specific objectives were set to guide the LUCID Project:

1. Test, develop, modify, and evaluate C&I to assess the sustainability of ecological, economic, and social systems at the FMU scale;
2. Develop analysis methods that establish the relationships between indicators and aggregate the results for reporting on sustainability;
3. Examine the relationship between national-scale (e.g., Montreal Process) and FMU-scale indicators;
4. Develop a research agenda based on the above work to further understanding and application of FMU-scale C&I; and
5. Develop a strategy to implement FMU-scale C&I throughout the Forest Service.

As a result, six interdisciplinary national forest teams working on eight national forests were selected to participate in the LUCID Project including the Ottawa National Forest in the Upper Peninsula of Michigan; the Allegheny National Forest in northwestern Pennsylvania; the Modoc National Forest in northern California; the Blue Mountain Province Forests of eastern Oregon (including the Wallowa-Whitman, Malheur, and Umatilla National Forests); the Mt. Hood National Forest in northwestern Oregon; and the Tongass National Forest in southeastern Alaska (see Figure 3).

During an approximately 2-year period, a coordinating team from the Forest Service Inventory and Monitoring Institute (IMI) worked with each participating national forests in a process of developing an FMU-scale monitoring program for sustainable systems. The development, analysis, and implementation of a practical set of local-unit C&I involved discussions with many affected groups. These included staff from the Forest Service, staff from other Federal agencies administering public lands adjoining the involved national forests, staff from State agencies responsible for administering State interests, and residents who were local stakeholders at each participating national forest.

THE LUCID EXPERIENCE: BENEFITS FROM FMU-SCALE SUSTAINABILITY MONITORING

Why the Forests First Participated

When the LUCID forests were first nominated for involvement in the LUCID Project, the nomination documents and the initial discussions identified perceived benefits for sustainability monitoring that can be categorized in three themes: (1) overall improvement to management; (2) stronger use and linkage between inventory, monitoring, and data management; and (3) improved collaboration.

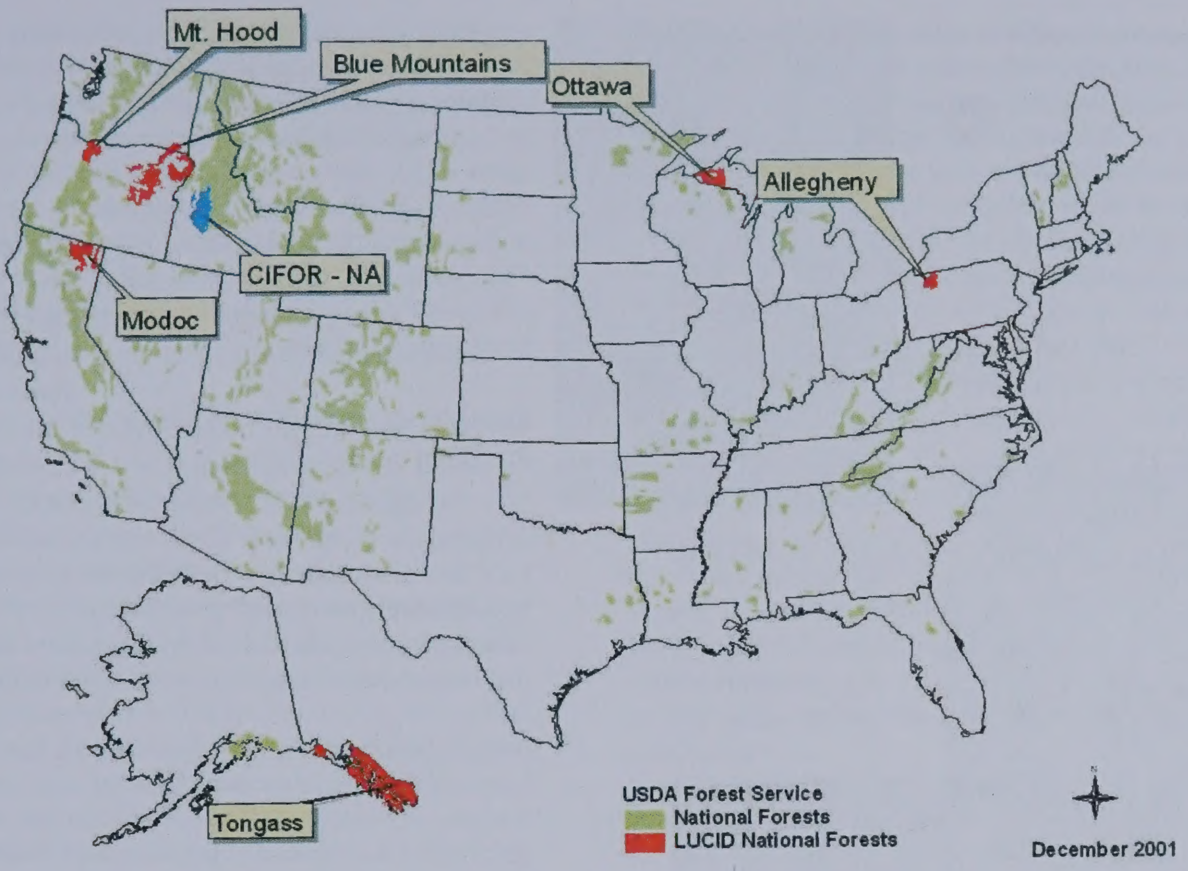


Figure 3. Locations of the LUCID Forests and the CIFOR-NA Site.

Improve Management

LUCID teams noted that they felt participation in the process might help them to expand their knowledge about sustainable ecosystem management and to identify key trends in indicators on their respective forests. Several teams noted that they felt this information would be particularly useful prior to forest plan revision and in ongoing monitoring activities. Some felt that assessing C&I could help them demonstrate some of the positive management actions they had taken over time and as a result develop better working relationships with partners. Additionally, LUCID teams felt that they might be better able to relate to management staff, and to the public, the tradeoffs between the multiple uses and values on the forest.

> *"Being able to complete this test prior to beginning forest plan revision was a key factor. The leadership team on the forest believed involvement in the LUCID test would expand our knowledge and provide technical tools to work with our publics on sustainability topics when forest plan revision begins. Identifying a suite of interrelated criteria and indicators for measuring ecological, economic, and social sustainability will be an excellent communication tool to display the multiple-use tradeoffs on this intensively utilized forest.... The report [will] help to identify trends with their key indicators and the kind of baseline data needed for monitoring. Looking at data trends over the next 3 to 5 years will establish a much better basis on which to make a forest assessment on sustainability."*
> *(Allegheny National Forest Team)*

Inventory, Monitoring, and Data Management

Several forests expanded on the potential utility of an FMU-scale C&I initiative to help in the areas of inventory, monitoring, and data management. National forest personnel indicated that they hoped through the test they might be able to identify the kinds of baseline data needed to help direct future monitoring and reduce uncertainty. The potential overlap and linkages between FMU-scale sustainability monitoring and other monitoring initiatives (e.g., forest plan monitoring) and information systems (e.g., NRIS) was a key issue for several national forests. A number of participants felt that they would be able to avail not only forest specialists but also research specialists and other regional expertise. Some participants wanted to build on their development and experience in ecological classification and inventory systems so that monitoring was specifically tied to other inventory and monitoring activities. Forest teams also identified that through an FMU-scale C&I approach they may be able to relate better to regional assessments.

> *"Our interest lies not only in the C&I evaluation but also in how this process may integrate with and enhance endeavors such as the implementation of the National Resource Information System (NRIS) and our current monitoring program."*
> *(Tongass National Forest Team)*

Improvements in Collaboration

Participants reported that they felt they might be able to use sustainability as a discussion point to form, cultivate, and sustain relationships with neighbors. The idea of stretching and testing the Forest Service view of sustainability to include neighbors, to bridge public and private lands, and to forge relationships with communities and partners was viewed as critical. In addition to providing another forum and opportunity for dialogue with the public, forest teams felt that an FMU-scale C&I process might help them develop technical tools and process approaches to help work with their publics.

> *"Mt. Hood National Forest is located 20 miles east of Portland and the northern Willamette River Valley and provides about 35 miles of continuous green-space west-to-east across the Cascade Mountains. Various entities provide green-spaces between Portland and Mt. Hood National Forest including, but not limited to, the Cities of Portland, Gresham, and Sandy, Metro Regional Government, Clackamas and Multnomah Counties, Oregon Department of Parks, and the Bureau of Land Management. Individually, each of the green-spaces provide unique opportunities, but imagine the possibility of connecting all of the green-spaces into a continuous link from the Portland Metro area across the Cascades, and the benefits this could provide to over 2 million residents! The sustainability of the individual green-spaces may not be an issue; however, forming, cultivating, and sustaining the relationships necessary to ensure a robust "Hood to Rose City" green-space could be daunting. Furthermore, what would the criteria and indicators of a sustainable forest management relationship be? Mt. Hood, along with green-space partners, would like to explore the possibility of developing criteria and indicators for social and political relationship sustainability through a linked greenscape natural resource context."*
> *(Mt. Hood National Forest Team)*

Emerging Benefits: Process and Product

Through the LUCID Project, the LUCID forest teams, forest supervisors, and the IMI LUCID team jointly explored both the **process** of how to develop and conduct a sustainability monitoring program and the potential **products** that can be developed from, or are needed for, such an effort. But our collective effort was designed not just to explore how and what to do but more broadly to evaluate whether such an initiative could be useful to national forests. To address this larger issue, the participants built on their original motivations for participating. From their experience during the test they looked forward; beyond the challenges of developing a set of tools and using them in an experimental way. They found that the results, the *products,* from sustainability monitoring and the *process* of developing the monitoring program and engaging others in a dialogue about sustainability were critical benefits.

The Product: An FMU-Scale Monitoring Program for Sustainability

In its broadest sense, FMU-scale sustainability monitoring is part of the adaptive management cycle that provides feedback for national forests management to inform the discussion and planning on management of sustainable systems. The focus is on describing the current state of ecological, social, and economic systems—a broad interpretation of effectiveness monitoring. A systems approach to sustainability monitoring can provide a framework for national forests to move beyond simple collection of data to provide a model to guide synthesis and interpretation of results to add meaning to forest and rangeland management. An

FMU-scale sustainability monitoring initiative can be used for the following:

- To synthesize information for comprehensive and strategic planning, such as forest plan revision;
- To serve as the core component of forest plan monitoring;
- To identify issues that require prioritization for management or further research;
- To detect and assess trends in a proactive fashion;
- To aid in more explicit consideration of issues at the FMU scale and to help clarify the context of the national forests within the larger socioeconomic and ecological systems;
- To organize a broad range of monitoring information so it can be accessed and used; or
- To convey information on the state of systems at the FMU scale to regional and national synthesis.

Some people view these C&I initiatives in two distinct phases: monitoring and assessment. The monitoring component is ongoing inventory of a suite of indicators that are tracked over time to identify trends. The assessment process is the phase of interpreting and analyzing the monitoring data against a set of reference value conditions. The assessment component may be done periodically, for example before forest plan revision, to help identify management issues and priorities (this approach is discussed in Chapter 14). We hold the perspective that the repeated collection of monitoring and inventory information has limited value without an analytical or assessment phase. Throughout the report we use the term *sustainability assessment* to mean the interpretation and analysis of sustainability monitoring information. Our focus was on developing both a process and a set of products, with which managers can determine what and how to monitor in order to assess progress towards sustainability.

The Process: Learning About Sustainability

The LUCID Project was developed as an interdisciplinary, cooperative endeavor. It involved a number of steps to move from the broad idea of sustainability to specifying the individual components for monitoring and then to analyze and synthesize the results of the individual components for the broader assessment of sustainability. Although this process was put in place solely for the purpose of guiding six different teams through the same steps, the process became as important as the products that result from sustainability monitoring.

> *"[M]any people have come away with a more intuitive understanding of sustainability and what it means for them as individuals and as a community." (Farrell 1998)*

Others have also stated "that the process of developing a sustainability indicator set is as valuable as the set of indicators that results"

Why Sustainability Monitoring?

Comments from LUCID forest teams and forest supervisors captured during a review meeting at the completion of the project:

"FMU-scale sustainability monitoring is not so much just for reporting as it is a learning process, a contribution to another end."

"This process is not necessarily to validate current management but to figure out what it is that we want to learn more about."

"It is a good tool for adaptive management."

"Not just listening, but a way to build some common visions—want to be able to have it open, malleable."

"FMU-scale sustainability monitoring is a way to have an ongoing process to work with the public, to have a way to create open dialogue with the public."

"The objective of FMU-scale sustainability monitoring is to put meaning to what it is that is being monitored (a framework with analysis). Previously, there has been mostly just monitoring not meaning."

"Our objective isn't solely analytical but the dialogue itself."

because "the selection process…focuses attention on the issue of sustainability" (Farrell 1998). Participants in the LUCID Project found that the lengthy discussions that result in the process of defining indicators, developing measures, setting reference values, and trying to analyze the results forced them to examine not only the integration of ecological, social, and economic systems but also the meaning of values.

LUCID participants also stated that the process of engaging the national forests staff and collaborators in a dialogue about sustainability and sustainability monitoring is invaluable. The result is that sustainability monitoring can be used to provide a basis for discussing what the public values (*a relative assessment of sustainability)* rather than an absolute measure of whether a system is in a sustainable state. The dialogue that results can help to tell the stories of the forest and through those to engage the public in a dialogue about their values of the stewardship of national forests.

OVERVIEW OF THE REPORT

The LUCID Project was a collaborative initiative among eight national forests, their leadership teams, and the Inventory and Monitoring Institute (IMI). Participating personnel all approached the test with a common goal of trying to determine whether FMU-scale sustainability monitoring was feasible and useful and how it could be done.

Though a common testing process was used to guide the six teams, each team approached the test in a different way, with different specializations and priorities, and with different results. Consequently, the results of the LUCID Project are not based on the experience of any single LUCID forest but rather on the integration of the experience of the six teams. Through their experience the teams identified many challenges, many things that needed to be done differently, and many areas for further work. The IMI team tried to write this report in a forward-looking way and respond to as many of these challenges as time and resources permitted. Many of these challenges, however, form the basis for further research or are issues to be addressed during implementation.

The LUCID Project was comprehensive and the reports have been written for a wide range of audiences both within and outside the Forest Service from forest managers to planners to those involved in implementing monitoring programs to collaborators.

To better serve the interests of our diverse audiences, the results of the LUCID Project are presented in three main parts: the executive summary; the main report; and a detailed criteria and indicator database available on compact disk (CD) or from the Institute's website (www.fs.fed.us/institute/lucid).

Executive Summary

The Executive Summary is oriented towards managers and provides highlights of the background and methods of the project but focuses on the management implications of the project[2].

LUCID Report

The intent is that the full report will serve both as a detailed explanation of the results of the LUCID Project and also as a type of desk reference for those exploring the idea of FMU-scale sustainability monitoring. Recognizing that different types of readers will want to focus on different aspects of the report, we have used a range of different organization and presentation techniques including sidebars, a glossary and acronym list; electronic hyperlinks to help you navigate through the document; chapter outlines and summaries; and icons associated with material appropriate to different interest areas. A User's Guide describing some of these navigational tools in more detail can be found at the front of this report.

The report is organized in five broad sections:

- Section 1 sets the context for the LUCID Project with discussions of sustainability, a systems-approach to sustainability, and issues of scale.
- Section 2 presents a brief overview of the methods used in the project including its collaborative and interdisciplinary aspects.

---

[2] Material contained within the Executive Summary is also contained within the full report.

- Section 3 presents the origin, development, and testing of the criteria and indicators through the six forest teams and is supported by the LUCID C&I Resource Database CD. This CD includes a comprehensive database of the descriptions and details for the principles, criteria, indicators, and measures; a starting conceptual model of the C&I built within NetWeaver; and copies of the other report appendixes that support components of the report and testing process.
- Section 4 addresses approaches, tools, and techniques for analyzing and assessing sustainability.
- Section 5 concludes with a discussion of the relationship of FMU-scale sustainability monitoring to other monitoring and forest management processes at a range of scales, recommendations for research and development, and recommendations for implementing a FMU-scale sustainability monitoring program.

CHAPTER 2.
A SYSTEMS APPROACH TO SUSTAINABILITY MONITORING

FRAMING THE APPROACH TO MONITORING FOR SUSTAINABILITY 23

- *Describes the value of frameworks to guide the selection of monitoring indicators and provides an overview of some commonly used frameworks.*

AN OVERVIEW OF SYSTEMS THINKING 25

- *Introduces basic concepts of systems thinking including issues of complexity, hierarchy, theory, emergent properties, and scale—along with implications for assessment.*

LUCID APPLICATION OF A SYSTEMS APPROACH 30

- *Discusses the adaptation of the systems framework through the LUCID Project.*

IMPLICATIONS 31

- *Identifies key differences between the systems approach and traditional approaches to monitoring. Highlights key advantages of the framework including a means to more fully define and prioritize items for monitoring, to serve as a model for synthesis, and to improve communication and collaboration.*

> *"Sustainability is not an absolute, independent of human conceptual frameworks. Rather it is always set in the context of decisions about what type of system is to be sustained and over what spatio-temporal scale."*
> (Allen and Hoekstra 1994)

FRAMING THE APPROACH TO MONITORING FOR SUSTAINABILITY

The construct of sustainability is broad and multifaceted; consequently, the task of selecting key indicators to monitor for sustainability can be challenging. Monitoring provides the essential feedback information regarding sustainability, but the information is useful only if it is the right kind. Acquiring useful information depends on establishing the appropriate criteria and selecting the right indicators. Frameworks are conceptual models "from which relevant indicators can be developed and selected" (Maclaren et al. 1996). The most desirable conceptual model—the best framework—integrates diverse system components and avoids unconnected indicators that may result in the "same fragmented view of the world that has historically led to some of our most serious problems" (Farrell 1998). Consequently the conceptual model characterized by the framework of choice should not only help in the selection of monitoring elements but also serve as a basis for synthesis, to guide the analysis that gave monitoring data meaning.

This chapter starts by highlighting various frameworks with special attention given to the systems-based framework selected to guide the LUCID Project. The following sections discuss systems theory as it relates to sustainability and monitoring and then summarizes the LUCID experience and value of a systems framework. Full details and development of the actual systems frameworks used during the LUCID Project can be found in Chapter 7.

An Overview of Monitoring Frameworks

Some of the common frameworks utilized to guide monitoring programs include issue-based, sector-based, ecosystem component-based, goal-based, causal-based, and systems-based. Ultimately, the framework used may combine selected attributes of several frameworks.

Issue-Based Frameworks

The issue-based framework organizes indicators according to problems within the area of study (e.g., riparian condition, insect outbreaks, visitor safety). This framework may receive more popular support than other types of frameworks because it deals with situations highly visible to the public and specific user groups. However, its shotgun approach to developing indicators may lack the structure provided by the explicit links to sustainability or policies found in other frameworks and will probably be limited in use to examining only known issues (Maclaren et al. 1996).

Goal-Based Frameworks

A goal-based framework employs indicators using the sustainability objectives developed from a stated vision or set of goals, such as maintenance of forest contribution to global carbon cycles. The strength of a goal-based framework is that it reduces the necessary indicators to just those relating to specific sustainability objectives. The limitation of this framework is that it may not specifically provide linkages between goals or include other concepts of sustainability (Maclaren et al. 1996).

Sector-Based Frameworks

The sector-based framework, within national forests administration, organizes indicators into relevant areas of work responsibility: the silviculture sector, the recreation sector, the road sector, the minerals sector. Sector frameworks may be most appropriate when the chief target audience is internal to management wherein the sectors can be tied to individual departments. This makes it easier to determine accountability for particular problems or positive results revealed by the indicators. A disadvantage of sector-based frameworks is they compartmentalize the indicators, which is not very effective for showing linkages across different areas, particularly when operating within an ecosystem management environment.

Ecosystem Component-Based Frameworks

The ecosystem component-based framework develops indicators for each ecological component including soil, water, and biota. This framework is sometimes applied to an entire ecosystem, such as a wetland ecosystem or an alpine ecosystem. A component-based framework focuses on specific ecosystems of concern; however, issues of scale and the boundaries and interactions between ecosystems make examining relationships and interactions difficult. This framework is less useful for developing indicators for social and economic concerns as these are not typically restricted to a particular ecosystem component (e.g., water) nor to specific ecosystems.

Causal-Based Framework

The causal-based framework considers the interactions between different elements within a system and organizes indicators into categories of stress, condition, and response. Stress indicators address why changes are occurring (e.g., the cause of degradation, i.e., fossil fuel emissions); condition indicators address what is happening or what is being affected (i.e., health, air, water); and response indicators address management actions or implementation tasks (e.g., miles of streams restored). The main difficulty with this framework is deciding what the connections are between the categories because causal links are debatable and often multifaceted. Similar to the issue-based framework, this framework is based on known stressors, thereby ignoring other ecological, social, and economic components that may be relevant to the broader concept of sustainability (Maclaren et al. 1996).

Systems-Based Framework

Systems Thinking
"A framework of thought that helps us to deal with complex things in a holistic way."
(Flood and Carson 1993)

The systems-based framework[1] considers the three main components of sustainability—ecological, social, and economic—and organizes indicators within these domains based on systems theory. Systems theory suggests that ecological, social, and economic systems are a group of interrelated, interacting, or interdependent constituents forming a complex whole. A systems-based framework uses the structures and functions (processes) of the systems as the organizing tools. A systems approach focuses on the contexts that allow for the production of goods, services, and opportunities to meet different values. Within a systems framework the focus is on the outcomes or states of systems and not on inputs or outputs. Systems cannot be inferred from *post facto* integration of functional resource outputs (i.e., timber, range, water). This is particularly applicable to forests since they are joint-production systems that simultaneously, not independently, produce soil, water, air, plant, and animal material. This framework is most effective for ensuring coverage of the three systems from which sustainability emerges and for examining interactions within and among the three main components of sustainability.

---

[1] A systems approach is differentiated here from a systematic approach (Kay and Foster 1999). Systematic refers to a methodical or ordered approach (Kidney 1985). The systems approach, although it may also be systematic, refers in this case to self-organized living systems that consist of an assembly of elements related to an organized whole (Flood and Carson 1993) that have emergent properties.

The Relationship of Systems Thinking to Sustainability: The Value of a Systems-Based Framework

As discussed in Chapter 1, sustainability describes a relative condition of systems. It may be best achieved not by sustaining the outputs of systems but by sustaining the contexts, the fundamental systems that sustain us by providing the capability to produce the values we need or desire. The structures and functions that comprise ecological, economic, and social systems are fundamental system properties; and by definition they are the criteria that describe the kinds of systems.

Starting from a systems orientation to understanding sustainability, we selected a systems-based framework to guide the LUCID Project. We felt that a systems approach would be very useful in two primary ways. First, it would more fully define the items for inventory and monitoring; and second, it would provide a model for synthesis and analysis of the data. A systems-based approach establishes a logical link from sustainability to monitoring as it helps place the monitoring component (the indicator and the data that supports it) in context. A systems framework provides a conceptual means of organizing a monitoring program that is significantly different from other indicator initiatives because it works with the premise that sustainability is not just about all the individual components (e.g., indicators) but about how those components are synthesized into a complex, interacting whole.

> *"A systems approach can help guide the development of inventory, planning, management, and monitoring problems for natural resource issues because a systems-based framework describes the components and interactions of the contexts we are trying to sustain."* (Hoekstra et al. n.d.)

A systems framework is also useful from a process perspective because it helps collaborators understand and communicate how individual components of importance interact together. The systems framework thus provides a common starting point for collaborators and a means of building a common language about sustainability.

Linkages Between Frameworks

Most other C&I processes do not explicitly describe the framework used to select indicators. Consequently, we have found it more difficult to understand other processes, their related interpretations of sustainability, and how those interpretations affect the choice of criteria and indicators. In contrast to the systems framework used by the LUCID Project, the Montreal Process (MP) and the Canadian Council of Forest Ministers (CCFM) appeared to have used a hybrid framework that combines aspects of component-based, issue-based, and goal-based frameworks.

Individual indicators are often common between C&I sets (e.g., LUCID and the Montreal Process); but the chosen framework establishes the logical relationship between the criteria and indicators and their measures. C&I sets developed from different frameworks or at different scales will measure different things. This means monitoring results from suites of indicators developed under different frameworks may require considerable effort to translate. This issue is discussed in more detail in Chapter 14.

AN OVERVIEW OF SYSTEMS THINKING

A simple explanation of systems might describe an ecological, social, or economic system as consisting of various structures (parts) and the functions (processes) by which those structures interact. However, understanding systems theory, and particularly how it relates to living systems, requires a more sophisticated comprehension of the complex nature of the whole: the kinds or types of systems, the parts of involved and possibly connected systems, hierarchy theory, and the issues of perspective and the role of the observer[2]. Because the concept of

> *"To be an effective systems scientist we must at the same time be both a holist, looking at the system as a whole, and a reductionist, understanding the system with more detailed forms."* (McPherson 1993)

---

[2] Readers wanting a more thorough review of systems thinking are referred to Allen and Hoekstra 1992, Flood and Carson 1993, Kay and Foster 1999, Sterman 2000.

scale, both spatial and temporal, and systems are closely intertwined, the following chapter on scale explores these topics in more detail.

Emergent Properties: The Whole is More Than the Sum of Its Parts

By standard dictionary definitions, systems are groups of interrelated, interacting, or interdependent elements forming a complex whole. Elemental interaction determines the structure and organization of the system; and in turn, the elements are influenced by that structure and organization (Kay and Foster 1999). This systems concept can be described generally by the theory that an item of knowledge or behavior can be studied only within the context of how it fits into other systems (Flood and Carson 1993). King (1993) notes that because a system is defined by both its components and the interactions between them, then a system description "simultaneously involves both structure and function—[and the questions] what are the components, how are they connected, and how do they operate together?"

Because of the interactions, living systems have emergent properties that are more than the physical and chemical ingredients of which they are composed. Nutrient cycling and carbon sequestering are examples of emergent properties of ecosystems. These emergent properties result from the synergies and interactions between elements and processes of these systems and are often only visible when you move up a scale in analysis.

Systems, Scale, and Hierarchy Theory

Living systems include both nested and nonnested hierarchies. Nested living systems contain every other system within them. For example, in Bailey's geographic concept of ecoregions, an observable landscape unit—an ecoregion—contains communities, each community contains populations, and each population contains its attendant gene pool (Bailey 1995). Nonnested systems—the large majority of living system hierarchies—are not so bounded but are rather a result of shared structures and/or processes that cross system boundaries, for example, organisms in communities and population systems. Hierarchies of the same kind of system exist in nested relationships more frequently than hierarchies composed of different kinds of systems. We would not expect, for example, a nested hierarchy comprised of ecological, social, and economic systems. Nested and nonnested hierarchies exist coincidently in time and space.

Hierarchy theory tells us that for nested systems the next larger system is the context for the next smaller system. At every scale, the context—the systems we are trying to sustain—changes and, consequently, so do the sustainability questions. In sustainability monitoring the interaction of scale and systems is a critical topic, particularly with respect to issues of data aggregation and analysis. This topic is discussed in detail in Chapter 3.

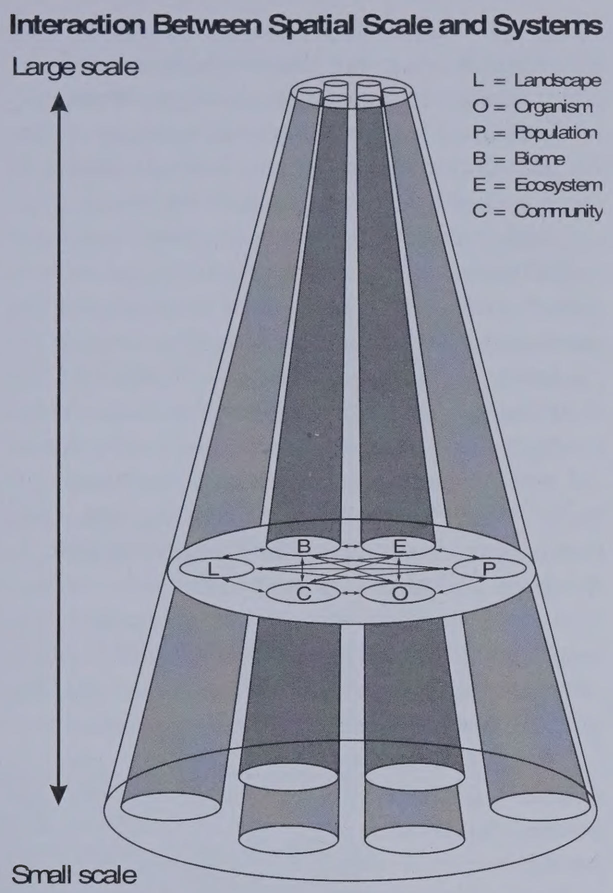
System Kind or Type

There are a variety of different kinds or types of systems[3]. Kinds of ecological systems include populations, communities, ecosystems, and landscapes. Kinds of social systems include individuals, families, neighborhoods, towns, and others. Kinds of economic systems may include individuals, families, firms, industries, and others. Although systems may have components in common, each kind or type of system has specific elements that interact in unique ways.

Confusing kind or type of system and spatial scale commonly occurs, particularly in ecology (Allen and Hoekstra 1992). System types such as cell, organism, population, community, ecosystem, and ecoregion can be hierarchically ordered; but they are actually a mix of both nested and nonnested systems. As a result, these types of systems are not spatially dependent; such that landscape systems are not necessarily spatially large and population systems are not necessarily spatially small. Spatial interactions are just one of many potential system interactions (Figure 4). Unfortunately, everyday use of familiar terms casually blurs meanings so that the terms lose detail. For example, in familiar usage *landscape*

---

[3] Some people prefer to use the image of systems and subsystems such that the ecological system is comprised of subsystems including organisms, populations, communities, and landscapes. To be consistent with systems theory literature, however, we use the terms *kind* or *type* of system.



Source: Allen and Hoekstra 1992

Figure 4. Ecological System Kind and Spatial Scale

often refers to a specific spatially scaled area, such as a watershed, but ignores the attributes that define that watershed; attributes such as the spatial arrangement of pattern. Details are equally critical for small and large landscape systems. The LUCID Project was grounded in a systems-based framework that differentiated between type of system and scale of system. Criteria and indicators, developed for each system type, attempted to identify the critical elements and interactions—emergent properties—independent of spatial scale (see Chapter 8).

Measurement from What Perspective: The Role of the Observer

All systems, by definition, are complex to some degree and therefore can be studied at various levels of organization and observed from various perspectives. Living systems can be overwhelmingly complex. A particular challenge associated with the complexity of living systems is that simple aggregation of lower levels is insufficient to explain higher levels. As Allen et al. note (1985) "apparently there is more to complex systems than lots of little bits of information. Part of that 'something more' may be found in the hierarchy that organizes complex systems." Systems and hierarchy theories have revealed an important portrait of the observer that is necessary to consider in any monitoring program. This portrait has particular relevance both for determining the observational perspective to take in developing measures and for establishing reference values.

The portrait can be summarized fairly simply: an observer can see different things about different living systems (ecological and socioeconomic) from different perspectives. As complex structures, populations are made of smaller structures and the population itself is a structure at a higher hierarchical level (Figure 5) (figures and descriptions adapted from Allen et al. 1985).

Boundaries prevent complete observation across adjoining systems. When a person observes from within the system of study, he or she can detect and monitor the component parts of the system. The interactions between the parts can be seen (Figure 6), but the system environment is obscure. In this situation the observations can be classified as "fine grain."

When a person observes from outside the system of study, the component parts are obscure; but the observer gains a "coarse grain" perspective of the system environment (Figure 7).

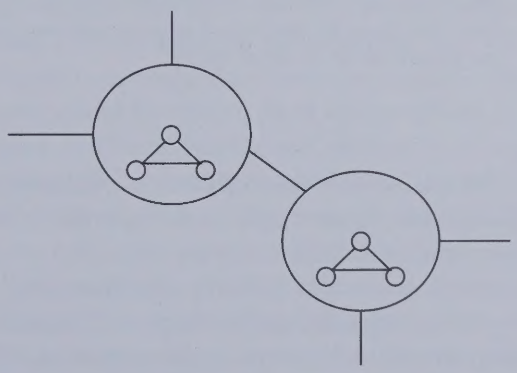


Figure 5. An illustrative full system composed of two entities with three parts each. This complete system is not observable from any single observational perspective.

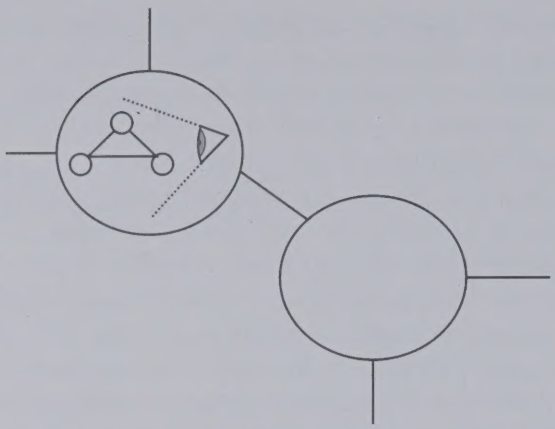


Figure 6. The person is making the observation from within the entity and can observe the parts and their interactions, an example of "fine grain" observation. (The eye indicates the position from which the system is observed.)

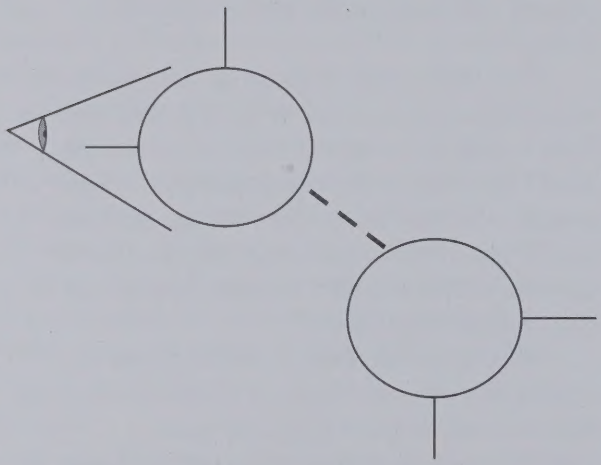


Figure 7. When the person moves outside the system, he or she can observe the phenomena at a broader level. In this case the observations can be classified as "coarse grain."

For example, within a forest (an ecological system) an indicator might be tree growth, which can be measured different ways. A forest mensurationist would typically determine tree growth by repeatedly taking height and diameter measurements and comparing them over time. These measurements are from a perspective outside the tree. A tree physiologist would determine tree growth by examining cellular productivity relevant to ambient moisture and nutrients. This appraisal comes from a perspective inside the tree. Not all examples are as clearly defined as this one; but because the cause-and-effect relationships regarding plant growth are relatively well known, the physiologist can predict the growth response of the tree from the measures taken from the perspective within the tree.

Within a regional economic system indicators might be used to monitor the trade balance with other regional economic systems or to monitor employment diversity. Observing these phenomena both from within the regional economy and from the perspective of the forest-products sector, a downturn in either the supply or the market for timber products will be viewed negatively. Similarly, from within a regional economy perspective for a forest-sector worker, there will be little tolerance for job loss. Observing the regional economic system from outside may reveal that perturbations and downturn in the forest-products sector is offset by growing tourism and recreational economy.

Many current debates regarding national forests evolve from conflict of perspective. Local communities usually observe phenomena from an inside-the-system perspective whereas the Forest Service must manage from both external and internal perspectives.

> *"The difficulty with conducting science at a scale significantly larger than ourselves [humans] is that the entities posited are the context of the investigators who are for the most part nested inside that which they study. Except for the whole planet, bounding entities larger than ourselves is difficult and our capacity to recognize structure and change at that scale is limited."*
> *(Allen et al. n.d.)*

Fire exemplifies the issues of observer position with broad meaning from both a socioeconomic perspective and an ecological perspective. When the observer is within the burned community, fire seems devastating. An internal perspective will observe that individuals and populations within the burned community are lost; a perception of destruction results. An external perspective will observe details of survival, and a perception of renewal and regeneration results. In this example, the perspective of the Forest Service must be from both outside and inside the community and must focus on overall community health and the regeneration and renewal of the community. An outside-community perspective may conflict with the perspective of community residents who are concerned about the survival of that particular community, of that special place, or of the jobs that might come from those specific trees—an inside-community perspective. Both the approach to monitoring natural disturbances, such as fire, and the perspective from which reference values are constructed can occur from either perspective. If the perspective for monitoring and reference value construction conflict with the perspectives between those who manage and the publics who are concerned about the issue, monitoring data may only fuel the debate.

The fire example illustrates the point that conflict arises when Forest Service perspective differs from that of the immediately affected public. Collecting monitoring data from one perspective without considering the other invariably aggravates the conflict. Each perspective is equally valuable and there is no right or wrong choice of perspective in a general sense. In fact, it is necessary for the observer to be able to move around and monitor from a variety of different perspectives. We need to measure phenomena of mutual concern from both perspectives so that we understand each other and can more effectively communicate.

Although focusing on the issue of observer perspective and its influence on monitoring was not explicitly designed into the pilot portion of the LUCID Project, this is an important step in the process and must be addressed as part of the final analysis. Determining whether to adopt one or both perspectives influences the selection of C&I and their measures. Therefore, to accommodate site-specific conditions and issues, discussions must clarify who holds which perspective early in the C&I selection process.

Assessing the State of a System

For some people, the discussion of sustainability leads to a desire for an ideal system state. As Allen et al (n.d.) note, "[it] is inappropriate to strive for a completely pristine system without humans and use that as the benchmark for sustainability." System integrity "thus implies the integrity of both system structure and function, a maintenance of system components, interactions among them, and the resultant behavior or dynamic of the system" (King 1993). Integrity is inherently a holistic, "whole-system property… [that] applies to the entire integrated system and not just one or more of its components" (King 1993).

Although any system loss of a component or specific interaction could be strictly interpreted as a loss of integrity, systems are relatively resilient. Natural systems often have inherent redundancies (e.g., numerous species within trophic layers). Changes in structure often result in changes in function and vice versa. Although the system structure may indeed be altered, the overall system function can often be maintained. Allen et al. (n.d.) note that a desired objective may be the "sustainability of functional units at all levels." The concept of resiliency may be more appropriate as a means of characterizing the state of systems.

If we want a system to persist over a relatively long period, it must be sufficiently complex so it can recover from large perturbations. Fragile systems, those that are less complex, are not inherently less sustainable. However, large perturbations can more effectively destabilize them since they lack the resiliency that results from complexity. Systems threatened by large perturbations may require greater energy inputs (e.g., genetic reintroductions of species that are limited in number and extent of area) to sustain them.

Temporal and spatial scale issues abound in the study of systems. Systems can be sustained for short periods of time much easier than for long periods, and sustainability at one spatial scale may be subsidized from another spatial scale.

If assessing the state of interrelated systems is a means to understanding sustainability, then the most preferred way of assessing the status of the systems would be some type of whole-system measure. Within ecological and economic systems some thought has been given to identifying whole-system measures. Gross domestic product (GDP) or gross national product (GNP) have often been identified, and in turn widely criticized, as a whole-system measure of economic systems. Within ecological systems energy flux exemplifies an attempt to apply a whole-system measure. However, as most ecological systems of interest extend over large spatial and temporal scales, it is "difficult to devise large scale, single-valued measurements of ecosystem integrity" (King

1993). Consequently, the ultimate measures for assessing the state of the systems will probably come from fine-scale levels of organization. King (1993) indicates that the challenge lies in devising some "collective integrated measure for the aggregate system." Although the idea of a single integrative measure has intuitive appeal, given that it may make comparison and standardization more feasible, the experience of the LUCID Project suggested that at the higher levels single measures were not as meaningful. The important variation, context, and explanation were lost when an overall measure was attempted. The specific issues and challenges associated with analysis, interpretation, and aggregation of results are discussed in Chapter 12.

The challenges with whole-system measures exceeded the intent and design capability of the LUCID Project, so for our purposes the C&I describe the structures and functions that compose each kind of ecological, social, and economic system. Measuring these structures and functions, then, is the way to monitor sustainability.

Integration Across Systems

The systems-based framework has great utility both to structure the identification of the key elements to be included in the monitoring program and to establish the basis for analysis; but to date there is no accepted theoretical or practicable model of sustainability that fully integrates ecological, social, and economic systems. "While we see social and ecological sustainability as intertwined, we can achieve clarity by analyzing them in part separately" (Allen et al. n.d.). For the LUCID Project we adopted a two-stage procedure to develop our assessment framework. In the first step we devised separate economic, social, and ecological system models to act as representations of the material world (Chapter 7). In the second step we modeled some of the interrelationships among the system elements (Chapters 8 and 12).

> *"Few existing models are based on the entire range of biological, physical and sociocultural processes, or adequately represent feedback links between and among human and environmental systems." (Manley et al. 2000)*

THE LUCID EXPERIENCE: APPLICATION OF A SYSTEMS APPROACH

The CIFOR-NA project screened a lengthy list of possible indicators to identify those feasible for application at the Forest Management Unit (FMU) scale in North America. That approach, along with an implicit as opposed to explicit use of a systems-based framework, produced a suite of indicators that the CIFOR-NA team members recognized was not complete.

The choice of a systems-based framework to guide the initial development of C&I for sustainability monitoring in the LUCID Project is different than most other C&I initiatives. The principles and criteria in the LUCID Project represent elements of the systems—ecological, social, and economic—we are studying. These elements are understood by examining the ways in which they interact with other elements of the systems.

The use of this systems-based framework guided the development of indicators. For landscape systems they might include structure indicators that describe the size and shape of landscapes and process indicators that describe the causes or sources of change that result in the pattern within and between landscapes. Likewise, population systems might include structure indicators such as density, age class, and sex ratios and process indicators such as reproduction, mortality, and immigration/emigration rates. Within the core indicators we selected for the LUCID Project, the majority of them are not fundamental systems measures but rather are synthesis indicators summarizing across the elements of systems.

The frameworks used for selecting and developing C&I establish the logical relationship between the criteria and indicators and their measures. In the context of the LUCID Project, the ecological, social, and economic systems-based frameworks have a hierarchical architecture that is defined by principles and criteria[4]. It is at the level of the measures or data for indicators where a more thorough examination of system interactions can be made.

---

[4] Principles are defined as explicit goals related to the overall objective of sustainability. Criteria refer to specific elements of the principle and as used within the LUCID Project define the architecture (structure and function) of the system.

The LUCID approach built on the CIFOR-NA project experience, and the team decided *a priori* to adopt an explicit systems basis to frame the LUCID pilot tests. This common framework provided a starting place for LUCID forest teams to develop a common language for discussing sustainability. On a practical level the systems approach also provided team members with a structure to start their tasks of testing the utility of indicators.

Additionally, the core team found great practical advantage in using a common framework for six different teams; it improved the possibilities of finding and identifying potentially common indicators and measures. Forest teams were encouraged to maintain a systems-based approach throughout the test but to also propose needed changes to the systems frameworks provided at the outset of the test. The tension between using a consistent systems-based framework while allowing for flexibility to adapt that framework was useful although some participants initially found it restrictive.

Adaptation of the Systems Framework at the Pilot Level

As part of their process, the LUCID forest teams reviewed the initial systems frameworks and the associated indicators and recommended changes including additions, deletions, and modifications to indicators and the frameworks that guided their selection.

Although many useful modifications were suggested, the national forests participating in the LUCID Project maintained the systems-based approach fairly consistently in the test. The systems-based frameworks and their evolution through the testing process will be addressed in Chapter 7.

IMPLICATIONS

Differences Between a Systems Approach and Traditional Monitoring Approaches

Participating national forests noted that the systems-based approach to monitoring was substantially different than most of the current Forest Service monitoring initiatives.

"Traditional monitoring is focused on goals, which are often not consciously tied to sustainability. For example, monitoring often occurs to meet a standard and guide that say you need good inventories, but there are no ties to critical points in ecosystem functioning that are important to track with the inventory. The LUCID process can help establish these connections." (Modoc National Forest Team)

Many Forest Service monitoring projects are either issue-based or threat-based (e.g., insect and disease monitoring). Forest plan monitoring, in contrast, often tends to be focused on implementation monitoring or monitoring for specific outcomes within a relatively short time horizon. As such, team members familiar with both monitoring approaches indicated that a systems-based approach to sustainability monitoring provided a unique and necessary view. Some participants thought it was particularly useful in identifying previously unperceived threats.

Some participants noted that their forest was not currently monitoring many of the key indicators identified within their LUCID Projects, though other participants found significant overlap with current monitoring. In both cases, a LUCID framework approach was seen as useful in identifying significant gaps in existing monitoring.

Regarding the three principle systems—ecological, social, and economic—participants reported that the systems approach to monitoring provided unique insight. Most of them indicated that the systems perspective for social and economic systems helped identify necessary components that were not part of any Forest Service monitoring programs. They further indicated that current monitoring initiatives tend to examine population systems or ecosystems but that an ecological systems focus identified the need for monitoring organism systems and landscape systems as well. Monitoring of both organism systems and landscape systems required skill sets that were less common in the Forest Service and consequently identified an area for potential increased collaboration.

Sustainability monitoring within a systems-based framework and the need for explicit

> *"The systems framework provides a mechanism for integrating monitoring items and understanding simple interrelated monitoring results and their relative importance to influencing or contributing to one or all of the C&I. The Monitoring Strategy for the Blue's Forests is not system-oriented by design, but several indicators represent current monitoring items. Tracing the C&I back through the monitoring strategy may reveal an apparent systems approach to some degree and highlight the areas missing from the framework. Most of our monitoring has been on ecological processes and functions and on outputs from them. LUCID has social and economic principles as two-thirds of the whole. This heightened emphasis on socioeconomics is very different from our current monitoring." (Blue Mountain Forest Team)*

consideration of scale was a central benefit for many national forests, specifically the need to understand sustainability within the larger geographic context than traditional monitoring has emphasized.

Key Advantages to the Systems Approach

Developing a Common Language and Structuring the Process

Team members at several participating national forests noted that the systems approach helped them think of the whole subject of sustainability and then focused them on the interrelated parts. They noted that the organizational framework, while an essential idea, was not easy and was a work in progress. However, they felt that the systems-based frameworks worked well to keep them on track of "what we were actually talking about" and provided a foundation for understanding interactions to provide a constant reminder that the lists of criteria and indicators "were not discrete and independent items" (Mt. Hood Forest Team).

> *"If nothing else, the systems framework is an excellent tool for documenting assumptions about management and the results of management." (Modoc Forest Team)*

The systems-based framework served as a baseline and reference point to capture points of agreement and disagreement and in this way helped develop a common language between team members while documenting the approach.

Prioritization and Integration

LUCID teams indicated that a systems approach highlighted the multidimensional character of forest management and "could be a useful blueprint for establishing a more comprehensive and effective monitoring program and, someday, for interpreting the information provided by the monitoring data" (Allegheny Forest Team).

Some teams found that they had a much more difficult problem in determining what was critical for monitoring since the systems-based approach expanded into a much deeper level of detail. Although prioritizing monitoring was viewed as very difficult, two advantages noted about the systems-based approach were that it helped ensure a more complete suite of indicators and measures and that the approach, utilizing a greater degree of science, would accommodate changing issues over time.

Integration between the three principal systems was identified as an area where challenges remain. Although the systems-based approach helped describe a specific system, teams reported that identifying explicit linkages and the complexity and interdependency of systems was still difficult.

A Framework for Communication and Collaboration

Throughout the LUCID Project the ability of the forest teams and core team to conceptualize and express the complex character of systems improved. This improvement was a distinct product of the testing process and will prove useful in the future.

Participants noted that the systems-based framework was a good starting point and was potentially useful to engage discussions with the public although it was complex and would need to be simplified for less technical audiences. One area that all have identified as important is the continued need to build a common understanding within and outside the Forest Service. This, they acknowledge, will require a simpler way to present the idea and to explain the values that come from a systems approach.

Some teams thought it was particularly useful because it was a way to address the broad range of perspectives within diverse audiences.

The Modoc Forest Team noted the systems-based framework could change "the nature of the communication… from small-scale (we want to do this project to get 'x' widgets or because we got some funding) to large-scale (does what we're planning/monitoring contribute to ecological, social, and economic sustainability in the short and the long term?)." The team stated, "If we are to become sustainable, then it seems that the thinking has to go this way, because, if nothing else, we no longer have the luxury (for a number of reasons) of uni-scale (mostly small) compartmentalized thinking, communicating and planning."

CHAPTER HIGHLIGHTS

- Systems are groups of interrelated, interacting, or interdependent elements that form a complex whole.
- Systems have emergent properties—that is, they are more than the sum of their parts.
- There are a range of different kinds of systems (system types), such as landscape systems, organism systems, family systems, and neighborhood systems that interact in unique ways in both nested and nonnested relationships.
- Systems can occur across a range of spatial scales.
- The observer's perspective in the measurement of a system affects the grain and extent of what can be observed and measured.
- Systems can be overwhelmingly complex such that simple aggregation of lower levels of data is insufficient to explain higher levels—instead, specific and conscious choices are required to identify in what ways, at what scales, and from what perspectives monitoring should be conducted.
- A systems-based approach uses the structures and functions (processes) of the systems as a framework—the criteria that frame the selection of indicators.
- The LUCID Project used a systems framework to construct an FMU-scale monitoring program to more fully: 1) define the items for inventory and monitoring; and 2) to serve as a model for synthesis and analysis of the data acquired.
- The systems-based approach is different than most of the traditional monitoring approaches within the Forest Service that tend to be issue problem, or implementation based.
- LUCID participants noted that the systems framework helped them think and construct monitoring for sustainability first as a whole and then as a way to help them focus on the components and their interactions.
- The systems framework was a means: to guide discussions in a common way and develop a common language; to identify missing components; to understand how individual components fit within the whole; to prioritize activities; to organize the synthesis of information; to better understand and communicate about the complex whole; and to move away from compartmentalized approaches to monitoring.

CHAPTER 3.
SCALE AND SUSTAINABILITY MONITORING

MULTISCALE MONITORING 37

➠ *Introduces the importance of scale, both spatial and temporal, in the design of monitoring programs.*

MULTIPLE SCALES: MEASUREMENT AND DATA ISSUES 39

➠ *Discusses the nature of systems with respect to scale, scale-dependent measures, and issues of data aggregation.*

THE LUCID EXPERIENCE: LESSONS IN SCALE 41

➠ *Reviews how the forest management unit (FMU) scale was defined in the LUCID Project and discusses implications for working beyond administrative boundaries and analysis issues.*

> "To be successful, [monitoring] needs to be a routine and integrated component of land management planning and be managed at a scale directly addressing the policies that affect land management."
> *(Mulder et al. 1999)*

BACKGROUND: MULTISCALE MONITORING

Systems reveal different character both in time and space. A single tree does not look the same or play the same interactive role in its parent community at 5, 50, and 500 years; nor does a forest look or function the same at 500 or 5,000 or 50,000 acres. Simply stated, scale—both spatial and temporal—matters; and because the systems we are trying to sustain reveal different characteristics at every scale, the sustainability questions invariably change accordingly. There is "no nature-given scale at which a system is sustainable;" and therefore, ideally, we should monitor for sustainability at a variety of scales (Allen and Hoekstra 1994).

Although critical in framing the issue, scale is often a "neglected component of sustainability discussions" (McCool and Haynes 1995). Defining scale is required to give the concept of sustainability meaning and is a necessary prerequisite for understanding the relationships between the systems and selecting the appropriate measurement methods.

The questions that will be asked at the local level will be very specific to the dynamics of the particular place and its resources and residents. Thus, employment may be a common factor to many scales, but the meaning associated with monitoring employment at the local level is very different than monitoring at the national level.

Different Scales Equal Different Questions

If we were to examine sustainability at the scale of a nation, be it the United States or Mexico or Canada, we might be interested in understanding the changes in employment in the forest-product sector. At this scale the questions that might be asked could include:

- How many people are employed in the forest sector now compared to 10 years ago?
- Are we producing more wood with the same number of people or with fewer?

At a local scale we might also be interested in understanding forest-related employment, but the questions or the means of verifying those questions are likely to be different. In a test of local-level C&I in Chihuahua, Mexico, team members were interested in questions that included:

- Do forest residents have equitable opportunity to participate in jobs associated with the community forest?
- Is employment distributed equitably between communities surrounding the forest or are certain communities suffering from more severe unemployment?
- Are people employed with good jobs that are safe and that provide wages adequate to house, feed, and clothe themselves and their families?
- Is the kind and nature of employment contributing to a sense of understanding and ownership about the forest?
- Are the forest managers doing things to employ more residents and to keep the jobs locally based, are the jobs being exported to other places, or are skilled laborers being imported?

Spatial Scale

Sustainability monitoring initiatives are occurring at a range of different scales. The national scale, characterized most prominently by the C&I sets of the Montreal Process and Helsinki Accord, is focused on examining the state of a nation's forests. Global assessments (e.g., WorldWatch Institute 2001) are also being used to track trends in the status of forests across the globe. At a regional scale a number of states (e.g., Pennsylvania and Oregon) have begun monitoring for sustainability; and other regional monitoring and assessment programs have been conducted, often defined by ecological regions such as the Mid-Atlantic region, the Great Lakes region, and the Sierra Nevada region.

Because the questions about sustainability vary at different scales, Cheng and Durst (2000) note that "nation-level sets of criteria and indicators for various regions of the world should be complemented by the development and implementation of sets of criteria and indicators defined by the forest management unit level." The need for scale-specific C&I was also a primary finding of the CIFOR-NA study (Woodley et al. 2000).

Experience has demonstrated that when indicators developed for larger scales are used for local-level scales they often do not address the system structures and functions and questions of sustainability. And while very broad and generically worded indicators (e.g., employment) can be applied at multiple scales, they typically have to be adapted to meet the local conditions for them to have any true value. Sometimes indicators are so inherently scale-specific (e.g., measures of the contribution of forestry to the gross domestic product) that they have to be significantly revised.

Although there should be linkages between sustainability monitoring initiatives at different scales so that they are complementary, monitoring initiatives at the local, or forest management unit (FMU), scale are not just an application of nation-scale material. And as ecological, social, and economic conditions vary greatly from place to place, the results from FMU-scale C&I processes vary greatly.

The FMU scale can generally be described as the scale at which management policy is actually implemented with on-the-ground activity and at which one or more ownerships decide how a land area will be affected by land and resource management activities. Total land area and ownership size might vary, but the focus on the FMU scale is based on the assumption that it is at the FMU scale that most of the decisions about management occur. The design of FMU-scale C&I is intended to help provide insight into the sustainability of the underlying ecological, social, and economic systems that function coincident with the FMU scale. There are a growing number of C&I initiatives focused at the FMU scale, but chief among them are the programs of the Center for International Forestry Research (CIFOR), the Canadian Model Forest Network, the USDA Forest Service LUCID Project, and the local-level C&I development efforts in Mexico.

CIFOR FMU Tests

A major project of CIFOR over the last decade has been the development of FMU-scale C&I that is appropriate to different parts of the world (CIFOR 1996). As an international research center, CIFOR has focused on field testing to identify C&I that is objective, cost-effective, and relevant to the sustainable management of forests. CIFOR tests have been conducted in Indonesia, Cote D'Ivoire, Brazil, Austria, Cameroon, Germany, and most recently, North America. In 1998 the USDA Forest Service plus international, Federal, State, and private organizations cooperated to host the North American test of C&I (CIFOR-NA) in Boise, Idaho. CIFOR-NA was designed to test the utility of FMU-scale C&I across a range of ownerships within a North American context. The test team was comprised of participants from Canada, Mexico, and the United States. The CIFOR-NA test site included portions of Boise National Forest plus some State and private lands.

Canadian Model Forest Local Level Indicator Project

The Canadian Model Forest Network has engaged a series of local-level indicator (LLI) initiatives at model forests in Canada and has more recently begun to encourage international model forest participants to establish more such initiatives (Canadian Model Forest Program 2000). The LLI initiative has used a very decentralized approach to encourage model forests and partners to develop C&I for monitoring sustainability. The size of each model forest varies as do the participants, but all include a range of land tenures and managers within an FMU-type scale.

USDA Forest Service LUCID Project

The purpose of the LUCID Project was to test the feasibility of monitoring sustainability at the FMU scale—such that monitoring is occurring at a scale commensurate with forest planning. Specifically, sustainability monitoring a the FMU scale involves understanding the forest in the context of ecological, social, and economic systems necessitating an approach to monitoring that goes beyond conventional administrative boundaries.

LUCID test sites ranged from 500,000 acres to 17 million acres and from a single national forest to three national forests working within one ecoregion province. In keeping with ecological, social, and economic systems, the study areas were not just limited to national forests system (NFS) lands.

Temporal Scale

When asked about issues related to sustainability, a Nuu-chah-nulth elder from one of the First Nations of Vancouver Island, British Columbia, replied incisively: "When are you going to start living like you plan on staying?" This simple question embraces the full robustness of sustainability. As a concept, sustainability possesses more than just a spatial scale; it also has a time element, a temporal scale. As Tainter (2001) notes, "When considering a statement containing the word sustainability, one should always ask of what, for whom, for how long, and at what cost?" Living or managing for sustainability is about developing a relationship with the earth that will persist. For the Nuu-chah-nulth—a people that have lived in the same part of the British Columbian coast for more than 10,000 years—"living like you plan on staying" evokes a sense of temporal scale that implies responsibility to, and consideration of, future generations far beyond what we normally envision. The issues of temporal scale and sustainability relate to the principles of intra- and intergenerational equity—the balanced distribution of benefits and costs not just within this generation but also for future generations.

McCool and Haynes (1995) ask "Over what period of time do we judge the sustainability of resource management?" The topic of temporal scale does not end with such a straightforward question; it has its own subtle convolutions as Dixon and Fallon (1989) observe: "The shorter the time horizon [in resource management decisions], the less likely any pattern of resource use will be sustainable over long periods of time." When temporal scale is ignored in resource management, the most common result is that the succeeding generation bears the costs of the preceding generation's benefits.

Monitoring, by nature, has a temporal component because it is intended to be repeated on a periodic basis to detect change. However, managers often treat monitoring as a singular, one-time event. In this context, however, we refer to monitoring as an ongoing process with the sustainability assessment being the synthesis and analysis stage that gives meaning to inventory and monitoring data. In this context sustainability monitoring tracks a suite of indicators over time to identify the changes in the state of systems. The assessment stage can give focused pictures at specific points of time (e.g., prior to forest plan revision).

MULTIPLE SCALES: MEASUREMENT AND DATA ISSUES

The multiplicity of scales by which sustainability can be examined immediately dismisses the notion that any particular scale or any one boundary might be the right one or the best one for monitoring. Inevitably, situations arise in which the reference values for a suite of indicators are met at one scale but not at another. For example, sustainable development at the local scale may result in contributing to unsustainable development patterns at a national level (McCool and Haynes 1995). The converse is also likely to be true, for example, when a forest does not meet the reference values set for it on a watershed-by-watershed basis while at a regional level those system structures and functions may well be within target. Thus, sustainability monitoring and assessment at multiple scales is suggested.

Typically, the smaller the spatial scale the more difficult it will be to resolve conflicts between competing objectives and the more likely that all indicators will not meet their reference values. At larger spatial scales resolving some of the conflicts between competing objectives may be easier in theory, but merely changing the scale of analysis may not resolve the underlying problem or conflict. Mechanisms to resolve conflicts across spatial scales are highly recommended as part of the monitoring design (McCool and Haynes 1995).

Scale-Dependent Measures

Living systems operate in similar fashions at multiple scales in time and space. For example, landscape systems on a decomposing log can have the same structure and function characteristics of landscape systems that operate in a watershed. Often, however, the way we measure (the protocols) living systems is scale-dependent. Consequently, although an indicator of a system attribute may appear to be common across multiple scales it may require different measures and metrics. Given this scale dependency in measures, C&I measures need to be developed that are particular to the scale of interest.

The measures of system sustainability differ at regional and FMU scales. Therefore, summarizing results of FMU sustainability assessments for several national forests within a region (administrative, ecological, or economic) would not be equivalent to a sustainability assessment at a regional level and will yield neither desired nor legitimately useful results. National forests are but one piece of the puzzle of forest ecosystems across the United States. A sustainability assessment at a regional or national level must consider the total landbase and associated systems that operate at these scales, entailing examination of national forests land in conjunction with private, State, and other Federal lands. And because cause-and-effect parameters are scale-dependent, it is impossible to take the FMU-scale C&I data sets for all national forests and additively summarize them to generate meaningful conclusions relevant to regional or national assessments.

For the LUCID Project, scale dependency figured prominently in selecting FMU-scale C&I and in determining how to measure them. Measures were uniquely designed to be evaluated in relationship to each other as a set so that the social, ecological, and economic systems could be evaluated at a common scale, the FMU. In some cases LUCID indicators contain subscale measures that apply at less than an FMU scale, but these subscale measures can always be reorganized to an FMU-scale measure. This allows the subscale measures, when consolidated, to be evaluated in relationship with the other FMU scale measures. For instance, there may be an ecological-subscale measure by watershed, or an economic-subscale measure by county, that would be reorganized to a forest-scale measure of all watersheds or all counties before evaluation occurs across all FMU-scale measures.

Scale and Data Aggregation

Just as matching the scale of the question to the scale of data collection is important so are issues of data aggregation. There is a great temptation to aggregate data collected at various scales to answer questions concerning a particular scale; however, this results in a data intensification challenge. The obvious benefits of this are increased efficiency in the cost and effort associated with monitoring. The aggregation temptation is facilitated by commonly defined data requirements prescribed across scales as core information requirements. Indeed, data may be collected at the FMU scale to assist regional or national monitoring, but those same data may not be useful either for addressing sustainability questions at the FMU scale or to respond to on-the-ground forest management needs. The nature of systems with respect to scale and the implications this has on assessing sustainability at multiple scales is not well understood and has resulted in frequent requests for mirror sets of C&I between scales and simple aggregation algorithms to facilitate upward reporting and sharing of data.

Considerations of scale must be designed into monitoring protocols for FMU measures. This is paramount to ensure that monitoring provides information about the systems that are being assessed. Though FMU-scale measures are not the same as those that should be applied to a regional or national set of C&I, they can provide rich narrative insight into assessments of sustainability at other scales. In turn, regional or national assessments of sustainability can describe the context in which the individual FMU sustainability assessment is conducted.

Scale issues are also complicated by whether or not systems are nested or unnested (see Chapter 2). For nested systems the issues of sampling and data aggregation are straightforward. Data are typically sampled at least one scale finer than the question of interest and are then aggregated upward. Sampling and data-aggregation in unnested systems are more difficult because the emergent properties of systems mean that simply aggregating data will overlook the synergistic effects of systems. For example, percent soil carbon can be aggregated using weighted area values while the volume of soil carbon/cubic meter cannot be aggregated, the latter because it is a process-dependent measure, the former because it is a process-independent measure.

THE LUCID EXPERIENCE: LESSONS IN SCALE

The Role of Scale Issues

Addressing scale issues specific to sustainability monitoring has two primary components: (1) identifying the spatial and temporal bounds for sustainability monitoring and assessment; and (2) identifying the smaller subscales within the study area in order to describe the monitored area with sufficient detail to be useful for management. Both components are critical in developing and selecting indicators, measures, and standards.

From a process perspective the LUCID teams found that an explicit discussion of these scale issues was critical in a number of ways. Talking about the bounds of the study area and the relative influences of boundaries was important for identifying relationships and linkages that the Forest Service has not traditionally prioritized. They focused on understanding the context that they were working within, which helped them place their discussions of the role of the forest and the management responsibilities of the Forest Service within a more regional sustainability context. Discussing this naturally led them to explore the potential roles and need for collaboration. They also discussed the systems approach and identified the questions of sustainability that are important at the FMU scale. Most teams recommended that a more structured discussion be conducted earlier in the process to clarify scale issues and questions specific to the FMU scale. In addition, this process also helped build an understanding of the relationship between FMU-scale sustainability initiatives and sustainability initiatives at other scales.

The process of identifying the subscales for study profitably engaged the teams. They discussed the relationship between the scale of data collection and the scale of analysis then identified the right balance of coarse versus fine analysis necessary for explaining sustainability relative to their forests.

Going Beyond Administrative Boundaries

Neither social nor ecological systems coincide with administrative boundaries; so most sustainability monitoring initiatives, regardless of scale, have gone beyond the administrative boundaries of a single forest tenure holder. Some other C&I initiatives at the FMU scale have defined the study area by including all areas under some common management regime, for example, a community tenure (e.g., CIFOR). Others have defined the FMU scale to include mixed management objectives (e.g., the Canadian Model Forests) based on joint agreement to engage in sustainability monitoring. Mixed-ownership models require careful consideration of the differing management objectives of tenure holders that may mean reference values and some measures will vary.

In the LUCID Project, teams thoroughly discussed the boundaries of interest. They recognized up front that the indicators and associated sustainability questions define the boundaries, and the boundaries typically do not coincide. Every LUCID team adopted test boundaries that were larger than the NFS lands. The Allegheny National Forest team, for example, used the unglaciated Allegheny Plateau (Ecoregion 212Ga) as the rough bounds of the ecological areas of focus. Similarly, the Modoc National Forest team chose an ecoregion to bound their area of interest. Both teams, however, used a flexible set of overlapping boundaries because social and economic indicators and questions were often associated with different boundaries such as counties. By contrast, the Blue Mountains Province team included three national forests over a three-State area within the same ecoregion province.

The issue of monitoring beyond Forest Service boundaries was not without challenges and debate. Defining what should be studied because it is related to sustainability and the forest and what should not be studied is very difficult. The less forest-dependent that human communities and their economies were, the more difficult it became to identify critical indicators and measures and to determine the bounds of the study. Generally, many of the social and economic indicators to be monitored are beyond the direct control of the manager. Most teams, however, felt that monitoring for sustainability needed to include lands beyond administrative boundaries in order to understand the systems and the context within which the national forests was managed. A number of the teams reported that they were very interested in being able to differentiate between the status of indicators over which the Forest Service had more direct control versus those that were more of a context within which the Forest Service operated. The approach used by the Mt. Hood National Forest team developed boundaries for study and analysis defined in part on the degree to which national forests personnel had control over management decisions. Collecting data on lands outside national forests proved to be no simple task. For many indicators, most LUCID teams were only able to collect data during the pilot process on national forests, primarily because of time limitations.

There are also challenges in sharing, analyzing, and displaying data across ownerships. When multiple industry landowners are included in cooperative sustainability monitoring, care must be taken to respect privacy and anti-trust provisions. These legal issues do not prevent such cooperative efforts, but they may slow a process in order to conduct it legally (Holt 2001). Sensitivity issues associated with acquiring data outside national forests may arise for certain indicators or in certain jurisdictions. Similarly, a coarse scale of display of results may project a value for a given area across a jurisdiction that it isn't truly associated with. For example, indicators associated with the health of quaking aspen may be mapped to elucidate the impact of disease; but this mapping may be projected over a city or town where the value does not truly apply. Alternatively, the data value for a given indicator may by default be applied equally to all parts of a specified area. For example, employment figures may be assigned one value across an entire county even though genuine differences are recognized between areas (e.g., from community to community) within that county. In addition to examining whether the spatial scale selected for the indicators is correct, there are a number of technical mapping fixes (such as the "ramping" function within Arc GIS software) that can help alleviate some of these problems. This, however, remains an area where sensitivity to the implied meaning of the results should be carefully considered during presentation and interpretation of results.

In the long run a collaborative approach that addresses sustainability within a given area across ownerships will be necessary to fully understand issues. Collaboration can also help improve efficiency of collecting and analyzing data.

Process: Defining the Boundary of Interest

The process of defining the boundary of interest was, beyond data management concerns, conceptually important. Ecological, social, and economic systems are inherently both nested, nonnested, and multiscaled. Nothing will be completely contained within any stated boundary (administrative or ecological). As a result, there will never be a perfect boundary or method to define boundaries. Nevertheless, the need to operate consciously and describe the boundaries that are used and the permeability of those boundaries does exist. LUCID forest teams used a variety of different approaches and put more or less focus on the process of defining the study area. They retrospectively noted that additional guidance on the process and value of defining the study area would be useful. In the process of defining C&I, the Mt. Hood team focused their discussion on scale and tried to carefully define the scales of interest and analysis when addressing the sustainability question for Mt. Hood National Forest. In other studies (see Doak and Kusel 1997, for example) the study area has been defined based less on geographic terms and more on stakeholder-defined sense of place, an approach that may be useful to consider.

The teams also indicated that flexibility in bounding the study area was very important. The unique nature of each of the national forests and the contexts in which they operate demand flexibility in defining the study area. LUCID forests ranged in size from 500,000 acres (of Forest Service land property) to 17 million acres, and included single forests or multiple forests working together. Some of the tests occurred in areas where the Forest Service was the primary land manager (e.g., the Tongass) and others occurred where the Forest Service was only one of many land managers. Testing across this range of spatial scales and groupings provided the opportunity to help identify whether there was a "best scale" or minimum or maximum size for an FMU-scale monitoring initiative. Despite the incredible range in size, the types of sustainability questions remained relatively constant across the forests, as did the scales for data collection and analysis. For example, small and large forests tended to use subwatersheds as the organizing scale for the same type of indicators even though the physical size of those subwatersheds varied greatly from forest to forest.

Teams had difficulty where the underlying contexts or management systems varied greatly across the study area. The Blue Mountain Province Forest Team for example, felt that the three forests within the province were similar enough to jointly participate in the test but did note that they faced short-term challenges in doing so (see Short-Term Challenges sidebar).

Short-Term Challenges to a Provincial Approach

The Blue Mountains Province is comprised of Malheur, Umatilla, and Wallowa-Whitman National Forests. Together, they encompass more than 5 million acres in three states. This area has a predominately temperate continental climate and is characterized by dry vegetation types. Frequent fire was historically the dominant disturbance. Human communities within the province rely on timber and forage from Federal lands. The area is dominated by rural lifestyles, a strong interest in natural resource management, and high perceptions about the quality of life in the province.

The three Blue Mountains Forests share common ways of looking at systems and situations, common community structure patterns, joint programs, and common problems. The management teams of these forests have integrated many management, planning, and monitoring functions. The three forests are looking at a joint team to conduct the coming forest plan revision through a province approach.

While there are many areas of commonality between the three forests, there are problems with conducting a large assessment across the entire province. Data for the three forests are not always collected at the same scale and in the same units. They do not all have the same GIS layers, and not all of the ones they do have are seamless. Assembling comparable information from the three forests was beyond the scope for the LUCID Project. With such a vast area to consider and with the complexity of the issues facing the forests, the LUCID team decided to narrow in on part of the province as a test area for our revised set of criteria and indicators.

The area selected for the test was Wallowa County, based on active involvement between local stakeholders, especially Wallowa Resources, a community-based nonprofit organization dedicated to sustaining Wallowa County's economy and ecosystems, and because data were available for many of the measures and data elements.

(Source: Abridged from the Blue Mountains Forest Team)

The Boundaries for Analysis

Data availability limitations, plus the time limitations of the test, meant that most forest teams, while intending to gather data from other ownerships, were generally unable to acquire it. This was particularly true for ecological information. Some ecological data were available outside NFS lands but not without substantial work and time commitment because they were secondary data from other sources. Socioeconomic data were more likely to be available on areas of land much broader than the national forests, often county or statewide data; but these data were difficult to collect in a short time. As a result, most of the forest teams concentrated their analysis for the test process generally on Forest Service ownerships (see Table 1). Within a regular monitoring program (as opposed to a test) teams felt that much of the data for lands outside Forest Service administration would be attainable however it would necessitate forming strong institutional arrangements and

Table 1. Boundaries for Analysis in the LUCID Tests

Forest	Outer Boundary
Blue Mountains	3-Forest Area (ecoregion province) Oregon
Tongass	Southeast Alaska
Ottawa	Ottawa National Forest/Western Upper Peninsula of Michigan and NE Wisconsin
Mt. Hood	Primary (NF), Proximate, and Extra-regional zones of influence, Oregon
Modoc	Modoc Plateau,California
Allegheny	Unglaciated Allegheny Plateau 212Ga (ecoregion), Pennsylvania

Table 2. Scales of Analysis in the LUCID Tests

Forest	Analysis Scales
Blue Mountains	Wallowa County
Tongass	177 *a priori* defined LUCID units
Ottawa	Ecological - National Forest Socioeconomic - predominantly MIWIEIA (Western Upper Penninsula of Michigan and NE Wisconsin)
Mt. Hood	Primary zone (NF)
Modoc	County / Forest / Watershed
Allegheny	Forest / County / Subbasin

developing collaborative partnerships. Teams recommended the need for concerted regional efforts at coordinated monitoring or data sharing in order to facilitate true implementation of LUCID-type sustainability assessments.

Coarse versus Fine Scale

Although the focus of the LUCID Project was to develop a sustainability-monitoring program at the FMU scale, we did not anticipate that every question would only be answered at the FMU scale. Indeed, the systems of study and the associated sustainability questions guided the teams to consider what subscales were necessary to tell the sustainability stories for the forest. Across the six tests there was much natural experimentation that occurred in determining whether to take a coarse or fine scale approach and in what areas (see Table 2).

The Ottawa National Forest, one of the smaller participating test sites, has a very detailed ecological land classification (ELC). Much of the existing management coincides with the ELC, so the Ottawa team wanted to provide as much monitoring detail consistent with the scales inherent in the ELC as was possible. As such, the Ottawa team had a very intensive, fine-scale data system for ecological indicators. What the testing process revealed was that ultimately it was a balance between obtaining sufficient information to inform management and the complexity of analyzing and understanding the results. Teams with more intensive scales of study (such as the Ottawa) did find utility in the fine-scale application although they did encounter challenges with data analysis and management within the analysis tools. Recommendations to help overcome some of these analysis challenges can be found in the Analysis Chapters (12 and 13).

In contrast, the Blue Mountains Team conducted much of their data collection and analysis at a coarse scale; and, this may result in greater difficulty in ascribing meaning and communicating useful results to management.

The scale of study also impacts the ability to detect changes. King (1993) notes that choosing the scale of detail (within larger area) to study is key. Large-scale measures smooth out fine-scale variability, and this option may remove noise and make detection of meaningful signals or trends more obvious. A coarser analysis may also, however, filter out fine-scale signals that may show developing problems. This issue led some teams to try and use a fine-scale approach to monitor land use and change as they felt that some potential important problems were being overlooked with the scale of monitoring that was currently occurring on the forest.

Relationsheds

The Mt. Hood National Forest is located 20 miles east of Portland and the northern Willamette River Valley and provides about 35 miles of continuous greenspace west to east across the Cascade Mountains. Originally, the Mt. Hood team wanted to use the tools of the LUCID Project to begin looking at the sustainability of these individual greenspaces and the possibility of sustaining them in a continuous link. It was felt that the most important aspect of "creating a sustainable Hood to Rose City Greenscape" would be forming, cultivating, and sustaining the relationships necessary to make this happen. So the Mt. Hood team had a specific interest in developing C&I for the sustainability of social and political relationships.

Sustainable systems are not bounded in ways that match conventional ecological, social, or economic patterns nor political jurisdictions. This becomes evident when mapping the cause-and-effect pathways associated with C&I related to Mt. Hood National Forest. While mapping cause-and-effect pathways is trying for biophysical aspects of sustainability, the Mt. Hood team became particularly aware of the issue as we were working on economic and social principles. We decided to approach the problem by carrying out a thought exercise of mapping the "relationsheds" (a term coined by Julia Wondolleck, 2000).

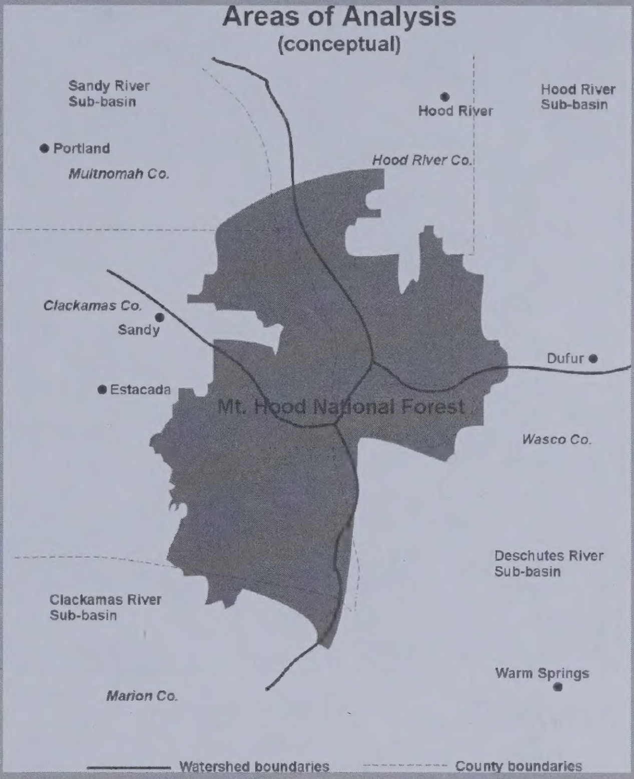


Figure 8. Mt. Hood National Forest Watersheds and Communities

We took a map of Mt. Hood National Forest and overlaid watersheds. We then explored the counties within and adjoining the forest to determine which exert primary influence and which could best characterize the social and economics aspects of the forest. This led us to identify the kinds of people influencing Mt. Hood National Forest and the locations, orientations, and attributes of these human communities (see Figure 8). This was done in the office without field checks and relied primarily on professional judgment. Still, we were able to identify several patterns of relationships. We identified a Portland metro influence, a Columbia Gorge influence, a Willamette Valley influence, a tribal influence, an eastside, a "New West," and a rural Oregon influence. Each characterization included a geographic orientation, a values orientation, and an interaction orientation. As we reviewed the exercise, we realized that the geographic approach provided insight into the place-based relationships but missed nonplace-based relationships. We needed to conceptualize both types of influence to capture the Mt. Hood National Forest relationshed.

In part this exercise reinforced the proposition that Mt. Hood National Forest is interdependent with a larger landscape. In developing sustainability C&I for the forest we had to adopt a view larger than Mt. Hood National Forest. For example, we found that the Columbia Gorge influence included parts of Washington and that we needed to include Bend, Oregon, though it is rather removed from the forest. These inclusions were essential to capture the "New West" culture and its influences. At this point in our thought exercise, we were clear that the question of scale and scope needed to be resolved before we could go much further.

In reviewing the picture of the relationsheds, we could identify "zones of influence," concentric zones based on the degree of control over the cause-and-effect relationships yielding the patterns depicted in our C&I. In a review of the patterns, we decided on three zones: a primary zone of influence [place based], a proximate zone of influence [place based], and an extra-regional zone of influence [non place-based] (Figure 9). The zone of influence can be characterized by the degree to which forest personnel have authority over policy and practice. In the primary zone, within the boundary of Mt. Hood National Forest, the Forest Service has primary jurisdiction. In the proximate zone, Mt. Hood has overlapping authority. Counties, cities, states, tribes, and other Federal agencies all share authority in this zone. However, most of the jurisdictions sharing authority are stable through time, adjacent in space, and share a common history in the management of the landscape. As important, in the proximate zone, the various jurisdictions expect to share a common future. In the extra-regional zone, forest personnel have no special authority and act as any other policy actor in influencing policy and action. Here the cause-and-effect relationships can be taken as exogenous.

As a matter of practicality, we decided that the [Mt. Hood] LUCID Project would focus on the primary and proximate zones of influence. Broader patterns of cause and effect are assumed to be exogenous and are measured at the boundary for influences. The primary and proximate landscape is Mt. Hood National Forest, the major subbasin watersheds, and associated counties in Oregon and Washington. This extends the usual focus on rural counties to include urbanized areas over which Mt. Hood National Forest has joint influence (i.e., water supply to Portland, wind surfing in Columbia Gorge, and mushroom or log markets).

The adequacy of the framework should be reviewed during the test phase of the project. At this point several observations can be made. First, this approach provides a way to organize watersheds, counties, and municipalities in ways that provide a basis for analysis. Second, the optimal unit of analysis for the ecological, social, and economic indicators varies. Finally, the zone-of-influence approach seems to have merit from an administrator's perspective.

(Source: Abridged from the Mt. Hood Forest Team)

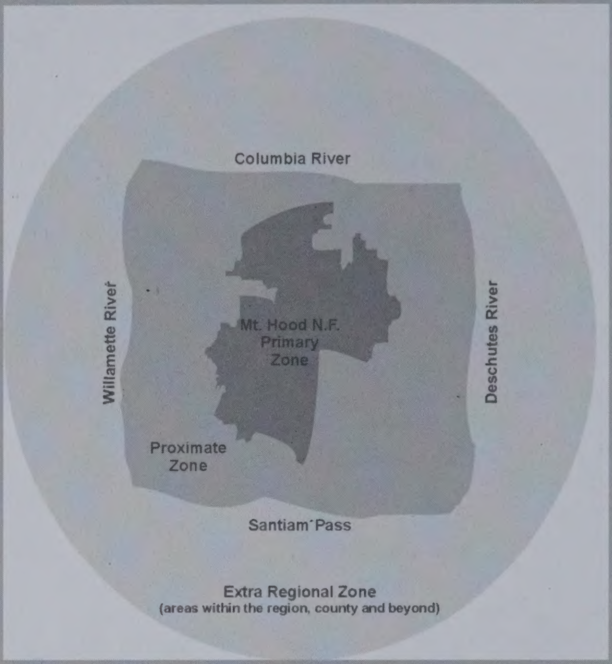


Figure 9. Relationshed Zones of Influence

Temporal Scale Considerations

The initial design of a monitoring system with respect to spatial scale so dominated the test that temporal scale probably did not receive enough explicit consideration during the LUCID testing process. From a process perspective, a focus on temporal scale was needed at the forefront in various places including the following:

- Framing discussions of sustainability values;
- Understanding systems and how systems change over time;
- Prioritizing indicator and measure selection to identify those most sensitive to change over time;
- Developing reference values (e.g., in the construction of some reference period either historical or future over which data values are examined to inform the process of setting reference values).

LUCID forest teams did use various approaches to consider temporal scale, specifically, within the discussion of reference values, which are discussed later in Chapter 10.

Analysis of the forest team's experiences suggest the following:

- Smaller study areas required fine-scaled data while larger study areas tended to have coarse-scale data needs;
- A forest-wide (e.g., FMU scale only) analysis of indicators may provide a quick view of the state of the forest but fine-scale data and analysis for most indicators are important to answer many management questions;
- Ultimately, smaller subunits (e.g., for ecological indicators—subwatersheds) were common scales for examining an area regardless of the overall size of study area;
- For economic and social indicators, the spatial scales tend to be larger than the forest, and these are undoubtedly the result of human mobility and its affect on social values, economic systems and the availability of data;
- Economic and social data are often most preferable at the scales by which people self-organize (e.g., communities) but are often only readily available at more administrative (e.g., states, counties, or census divisions) scales.

CHAPTER HIGHLIGHTS

- Systems are multiscaled; thus, managing for sustainability requires thinking across appropriate scales, spatially and temporally.
- Since the systems we are trying to sustain reveal different characteristics at different scales, the sustainability questions and measures potentially change accordingly.
- FMU scale C&I is not just an application of C&I from another scale but may also require the development of a scale-specific set of C&I.
- The LUCID Project focused on developing a program for monitoring sustainability at the forest management unit (FMU) scale—the scale commensurate with forest planning.
- Since ecological, social, and economic systems do not coincide with administrative lines, the study areas included NFS and non-NFS lands.
- Because systems are both nested and nonnested, common boundaries cannot be defined that are consistently meaningful; therefore, methods and tools that facilitate working at and across multiple scales are needed.
- The nature of systems (nested and non-nested) and the scale-dependency of measures mean that all data cannot be simply aggregated to attain a result at a different (e.g., regional or national) scale.
- Although simple aggregation between scales (e.g., FMU to regional to national) is not feasible, FMU-scale assessments can provide rich narrative insight into sustainability at other scales.
- Scale must be explicitly considered in the development of monitoring protocols.
- Explicit discussion of scale and the process of defining the study area can further understanding of systems and sustainability, help build collaborative relationships for data collection, and clarify the meaning of indicators and measures.
- Although primary analysis occurred at the FMU scale, data must be collected and analyzed at finer scales in order to facilitate interpretation of the results.

Section 2:
Methods

Chapter 4. LUCID Test Methods

This chapter provides a broad overview of the methodological approach used in the LUCID Project with a focus on the applied research orientation and the interdisciplinary team approach.

Chapter 5. Collaborative Approaches to Sustainability Monitoring

Introduces why the diverse values of sustainability need to be designed into a monitoring program and outlines the role of collaborative involvement in FMU-scale sustainability monitoring.

CHAPTER 4.
LUCID TEST METHODS

This chapter provides a broad overview of the methodological approach used in the LUCID Project in a summary fashion. Later chapters in this report elaborate on many of the individual steps and details, evaluate the feasibility of the process, and make recommendations about improving the process and consequently the products.

APPLIED RESEARCH IN FOREST MANAGEMENT UNIT C&I: THE LUCID TEST 51

- *Introduces the methodology of the test including* lessons learned from elsewhere, the selection process for the LUCID Project and the value of the six pilot tests.

METHODS OVERVIEW 54

- *Reviews the adaptation and development of the C&I through the testing process.*

AN INTERDISCIPLINARY APPROACH 59

- *Discusses the teams involved in the LUCID Project including the LUCID core team, the forest teams and the forest supervisory team, and recommends team composition.*

> "We …are interested in evaluating the use of C&I as a way of monitoring our management actions on the ground. This effort will also provide an opportunity for evaluating C&I as a tool for improved efficiencies and accountability. We have funded a project to pilot test the implementation of C&I at the FMU scale…"
> *(Chief Operating Officer, USDA Forest Service)*

APPLIED RESEARCH IN FOREST MANAGEMENT UNIT C&I: THE LUCID TEST

Although the concept of criteria and indicator monitoring has been around for more than a decade, the development of sustainability monitoring at the forest management unit level is still in its infancy. To date, the three primary FMU- scale sustainability monitoring initiatives worldwide are the CIFOR tests in seven sites including the North America test held in Boise, Idaho in 1998; the Canadian Model Forest program local level indicator initiative (LLI) that is occurring on the 11 Canadian model forests and has also been adopted by some of the international model forests; and the USDA Forest Service LUCID Project. Other countries and organizations are working on FMU-scale initiatives, including LUCID cooperation with initiatives in Mexico, but none have progressed to the extent of the above initiatives.

Lessons Learned from Elsewhere

The tools, techniques, and approaches developed through the CIFOR initiatives are well established and provided a useful foundation for the LUCID Project. CIFOR established a consistent process for testing (Prabhu et al. 1999), and each test has modified indicators from a common starting point. CIFOR was one of the first organizations to indicate a need to develop specific measurement protocols (verifiers) although this work is still in progress and largely focused on methods most appropriate in tropical, developing nations. CIFOR has also begun to explore the value of reference values and methods of integrating the results of the tests (Mendoza et al. n.d.).

The Canadian Model Forest LLI initiative has a similar focus on C&I for FMU-scale sustainability. Although they are all loosely related to the Canadian Council of Forest Ministers (CCFM) national C&I framework, no common method or coordinated approach was taken in the LLI project. Each model forest approached the task of developing C&I with different methods and has implemented monitoring to varying degrees. Recently, the model forest network has begun to compile the various forests approaches and results (von Mirbach 2000a, Natural Resources Canada 2000) but there are no current plans for identifying a core suite of indicators.

The CIFOR and Canadian Model Forest LLI initiatives both have provided context and lessons for the USDA Forest Service LUCID Project. In particular, the CIFOR-NA test provided the foundation for the LUCID Project. CIFOR-NA was an expert-based (not local team) study that was more narrowly focused on testing suites of existing indicators. The test did not develop detailed protocols (measures) for each of the indicators, nor did it develop reference values for measures, although it did explore these issues and stress the importance of them. The CIFOR-NA team also did not have the time to focus on synthesis and analysis methods, but it did suggest some ideas that merited further exploration. The CIFOR-NA test formed a firm foundation for the LUCID Project and the LUCID team (sharing common team members with the

> *"The [CIFOR] tested indicator sets were developed at the national level and do not translate well to the forest management unit. Indicators will only work when they inform management." (Woodley et al. 2000)*

CIFOR-NA test) used the lessons learned from this test to structure the LUCID approach (see 'Key Lessons' sidebar).

Chapter Content

One of the primary findings from the LUCID Project is that the *process* of developing a sustainability-monitoring program at the FMU scale is as important as the *products* that result from it. As a result, the methodological approach used in LUCID is important to document not just because of the need to explain how the results were obtained but to identify the important steps in a process that would be useful for other forests considering implementation.

This chapter provides a broad overview of the methodological approach used in the LUCID Project in a summary fashion. Later chapters in this report elaborate on many of the individual steps and details, evaluate the feasibility of the process, and make recommendations about improving the processes and consequently the products.

Team composition and approach was a very important factor in the ability of the forest teams not only to accomplish the tasks but also to develop a learning culture together. Consequently, the final section of this chapter provides detail on the interdisciplinary approach and experience.

Selection of Forest Teams

In March of 1999, a call went out to the regions to nominate pilot areas "interested in evaluating the use of C&I as a way of monitoring our management actions on the ground" through a national test of FMU-scale C&I. The test was described as a way to provide an opportunity for evaluating C&I as a tool for improved efficiencies and accountability and to evaluate linkages with other monitoring efforts including inventory programs, regional assessments, and national-scale C&I.

The forest pilots were selected based on the full support of the forest supervisor and regional forester and the extent to which they met a series of other criteria including:

- At least 18 to 24 months away from beginning forest plan revision, or have recently completed a forest plan revision (i.e., not currently in revision process);

Key Lessons from the CIFOR-NA Test

- Indicators will only work when they are referenced against a standard.
- Documentation and explanatory material for indicators and methods including definition, descriptions, sensitivity, theoretical rationale, and other factors are absolutely critical but are poorly documented in most other sets of C&I. The CIFOR-NA test built standardized evaluation forms (although they were not in a database and not searchable) to begin documenting this information. Since that time, CIFOR has built an interactive database (CIMAT) that helps structure this process and provides background information on existing C&I.
- There are serious nomenclature challenges in the terminology used by many C&I processes to describe criteria and indicators. Some of these issues persisted at the end of the CIFOR-NA test.
- Indicators developed at a national scale do not translate well to the local scale. The methods and questions of sustainability are different at different scales.
- Indicators must be adapted to local conditions, and adaptation principally occurs in the methods and reference value area.
- Real testing and adaptation of C&I don't occur until you collect data and analyze results.
- The development of economic and social indicators related to sustainable ecosystems is still in its infancy. Most economic indicators, for example, are still at a national scale.
- Although the ecological indicators were loosely organized by a systems framework, the key components of systems needed to be used up front to guide the process of developing C&I.
- Indicators that measure enabling condition (e.g., presence of legal and institutional frameworks for sustainable forest managment are normally larger scaled issues than at the FMU scale.
- Scaling social indicators (e.g., identifying measurement units and reference values) is very difficult.
- The integration of the ecological, social, and economic principles remains a challenge. More work on theoretical integration and on tools to assist in that integration is needed.

(Adapted from Woodley et al. 2000)

- Current ecological, social, and economic data available;
- An up-to-date operational information management system in place (data bases, GIS, etc.);
- Have or can acquire skills necessary to complete assigned tasks within required time frames;
- The support and willingness of the State forester to participate;
- Opportunity to collaborate with ongoing large-area assessments or other sustainability studies;
- Opportunity to include lands outside national forests boundaries in the evaluation (State, private nonindustrial, private industrial, etc.) and the willingness of other landowners to participate;
- Opportunities for involvement with a wide array of research partners; and
- Ecological and geographical diversity.

The Value of Six Pilot Tests

The involvement of the six forest teams was focused largely on the first two LUCID objectives:

1) testing, developing, modifying, and evaluating C&I to assess the sustainability of ecological, social, and economic systems at the FMU scale; and
2) developing analysis methods that examine the linkages between indicators and aggregate the results for reporting on sustainability and adaptive management.

Based on an initial set of C&I and a common approach developed by the core team, the participation of six test sites provided an opportunity to explore these objectives over a wide range of conditions and in a variety of situations. Although the overall process to the LUCID Project was standardized, great flexibility was needed during the research process to develop and revise the process and to explore the feasibility of FMU-scale sustainability monitoring over a broad range of conditions. Each forest team had different base conditions (ecological, social, and economic), different geography, slightly different team structures and approaches, different working styles, different forest supervisor objectives, different management issues, different levels of expertise in inventory, monitoring, and planning, and a myriad of other differences. In short, the differences between the forests reflected the diversity of national forests within the system. Consequently the selection of six forest teams representing forests across the country in this range of conditions was critical to the test.

As a result of the forests' initial differences and the ways that their teams approached the LUCID Project, each team ended up focusing their skills and attentions on different components. Some of the forest teams focused on the adaptation of indicators and development of measures on specific subject matter; some focused their attention on setting standards and acquiring existing data; others focused on analysis and reporting. Time, resources, and the fact that the process and products for sustainability monitoring at an FMU scale were being developed during this test meant that no one forest team was able to complete all steps and tasks fully.

The six forest tests and the applied-research approach to the LUCID Project enabled the exploration of a wide range of questions including:

- Can a systems approach to sustainability provide a useful theoretical and organizational framework for C&I monitoring from the selection of indicators to the integration of results?
- Is there a core C&I that appears common across a range of forests?
- What indicators or measures are more variable across forests?
- How do we define the FMU scale?
- To what extent does FMU-scale C&I monitoring overlap or relate to existing monitoring?
- What kind of information and guidance can management gain from FMU-scale sustainability monitoring?
- What are the best tools and techniques for sustainability monitoring at the FMU scale?
- What are the major benefits from sustainability monitoring?
- What areas remain to be further explored through research and development?

The answers to these and related questions were not known prior to the test; consequently, the ability to test these ideas experimentally across six different national forests was critical. Taken as a group, the results of the six forest teams can be combined and analyzed to develop a more streamlined process and more rigorous products for future use.

METHODS OVERVIEW

Using an applied research approach, the IMI core team developed a process that was intended to be flexible but consistent on each of the six forests (team structure and work style are discussed at the end of this chapter). The intent was that each forest team would start from the same place and follow the same process but have the flexibility to adapt the criteria and indicators and develop measures and reference values appropriate to test sites. The core team worked in a collaborative fashion with each forest team, using a workshop forum at each major step of the process:

- Workshop 1. Introduction to sustainability and C&I
- Workshop 2. Frameworks for evaluating: Systems frameworks (principles and criteria) and indicator evaluation and adaptation
- Workshop 3. Measures (verifiers) and conceptual modeling
- Workshop 4. Analytical modeling and the development of standards
- Workshop 5. Analysis of results

Appendix 4 outlines the main steps in the process, the approximate timing, and the expected products from the test as they were originally described. Appendix 5 provides a description of the overall process and major tasks as described by the Ottawa Forest Team.

Between workshops, the forest teams worked more independently, consulting with the core team, with other forest staff or collaborators, and with other forest teams as needed. Given that the forest teams had their start times staggered over about a six month period, there was some variation between the materials provided to the earlier teams than those that started later. The three teams (Ottawa, Allegheny, and Blue Mountains) that started early in the process made suggestions that led to the modification of some of the tools (e.g., database structure, workshop content, and timing) in order to make them more helpful.

The Initial LUCID C&I

The foundation of the LUCID tests was an initial set of C&I provided by the LUCID core team. The intent was that this initial set of C&I built on the results of previous testing of local-level indicators would provide a common starting point to help frame the LUCID Project. The initial set of C&I contained the best representation to that date of a suite of FMU-scale sustainability indicators but it had yet to go through extensive testing under a range of conditions. Based on the recommendations of CIFOR-NA, this initial C&I set was organized within a systems framework and consisted of principles, criteria, and indicators with little material available on measures or reference values. The forest teams were charged with testing and adapting the principles, criteria, and indicators and developing and testing measures and reference values.

Although the CIFOR-NA C&I set served as a starting point, the core team reviewed the Montreal Process C&I national-level suite; the Canadian Council of Forest Ministers national level suite; the EPA (EMAP) and the equivalent Canadian (EMAN) ecological indicator suites; the recently compiled CIFOR suite of indicators from all tests (CIMAT); the initial draft indicators from the Great Lakes Forestry Assessment (GLFA); and indicators suggested in a number of research articles (see Table 3 and Appendix 6). Where gaps were identified within the CIFOR-NA suite of indicators they were filled by selecting indicators from the other sets. Because nomenclature is important to testing, the element names were all revisited in order to evaluate the following:

- Remove measurement methods and standards from indicators;
- Remove directional intention/preference from criteria and indicators;
- Broaden wording to include forested and nonforested ecosystems as well as NFS and non-Forest Service ownerships; and
- Make wording parallel between elements.

Accompanying the initial list of C&I provided to the forests was an associated database of

Table 3. Example of Comparison Between the Initial LUCID C&I and Other Suites of Indicators Tracing Origin and Overlap (See Appendix 6 for the full table)

LUCID Initial Criteria	LUCID Initial Indicators	CIFOR - NA (Boise) Indicators	Montreal Process Indicators	Canadian Council of Forest Ministers Indicators
C3.1 Wealth and capital accumulation	3.1.1 Community economic trade balance (imports and exports)	No equivalent	No equivalent	No equivalent
	3.1.2 Land base available for production	2.2.7 Distribution of, and changes in, the land base available for timber production are identified	10. Area of forest land and net area of forest land available for timber production 11. Total growing stock of both merchantable and non-merchantable tree species on forest land available for timber production	5.1.2 Distribution of, and changes in, the landbase available for timber production
C3.2 Production and consumption considerations	3.2.1 Annual and periodic removals of products (timber and non-timber)	2.2.5 Annual and periodic removals calculated by area or volume prescribed	13. Annual removal of wood products compared to the volume determined to be sustainable 14. Annual removal of nontimber forest products compared to the level determined to be sustainable	5.1.1 Annual removal of forest products relative to the volume of removals determined to be sustainable 5.3.3 Utilization of forests for nonmarket goods and services, including forest land use for subsistence purposes
	3.2.3 Money spent by visitors in local communities (by activity)	2.4.2 Total expenditures by individuals on activities related to nontimber use	No equivalent	5.4.2 Total expenditures by individuals on activities related to nontimber use
	3.2.4 Value to products including value-added through downstream processing	No equivalent	29. Value and volume of wood and wood products production, including value added through downstream processing 30. Value and quantities of nonwood forest products	No equivalent

information for principles, criteria, indicators, and measures (originally termed ‘verifiers’). An evaluation form was developed to guide the teams through testing of indicators and measures (see Appendix 7). This form paralleled the database fields and contained explanations and evaluative questions. The fields in each of these forms varied by element type but commonly included definitions, descriptions, relationship to sustainability, and evaluative questions to help track the modifications and changes to the elements. This database was populated with information from the CIFOR-NA test (originally prepared only as a word document) and from other sources (e.g., MP, CCFM, etc.) as available. Although an initial core suite of measures had not been previously developed, forest teams were encouraged to consult the CIFOR-NA indicator evaluations for suggested methods.

Forest teams were asked to document their evaluations and development of the C&I within this common format. To assist in the process, pilots were also provided with additional documentation including the original testing material and resource book from the CIFOR-NA test, the United States First Approximation Report (Montreal Process), Canadian Council of Forest Ministers C&I reports, the Tropenbos Institute’s book on the hierarchical framework of C&I (van Bueren and Blom 1997), the Guide to Sustainable Community Indicators (Hart 1999), and other material from CIFOR and other institutions as appropriate to the pilot needs.

Review, Adaptation, and Development of C&I Through the Test

Given a systems framework, a common set of initial C&I, and the associated database of information, the six teams were instructed to review the suite of principles, criteria, and indicators and tender one of four possible responses: (1) accept; (2) accept with modifications; (3) reject; or (4) propose new elements and document their rationale (Figure 10). The teams were also directed to maintain the systems framework approach although they could suggest changes to the way the systems were defined (modify principles and criteria) and adjust where indicators fit best within the systems framework. Core team members assisted through the initial reviews of principles, criteria, and indicators to explain their rationale for including them in the suites of indicators. Although the core team attempted to remove nomenclature problems, the forest teams identified a number of problems that still remained with the core suite of indicators. Forest teams were asked, where possible, to keep the wording of indicators generic enough that they might apply across all national forests (e.g., not exclude certain forest or nonforest types in the wording).

After the initial review through the indicator level, forest teams proceeded to develop measures, data elements, and reference values for each indicator. The process was iterative; consequently, the entire suite of C&I was fluid until the completion of the test. Forest teams noted that their final suites of C&I were works in progress and that as new information arose (e.g., sensitivity testing, new data sources, experience), measures and data elements (and perhaps indicators) might shift over time.

One of the principal tasks of the forest teams was to research and develop measures for each indicator. They were encouraged where possible to use standard measurement protocols if they provided the right kind of information at the right scale, but the teams were instructed to not be driven by existing data if they did not provide the required information. Although measures varied greatly from forest to forest, there was, in most cases, a great deal of overall commonality between the concepts that forests were trying to measure (for a detailed discussion see Chapter 10).

Reference values (also commonly referred to as standards, benchmarks, or norms) had been suggested as a critical component to sustainability

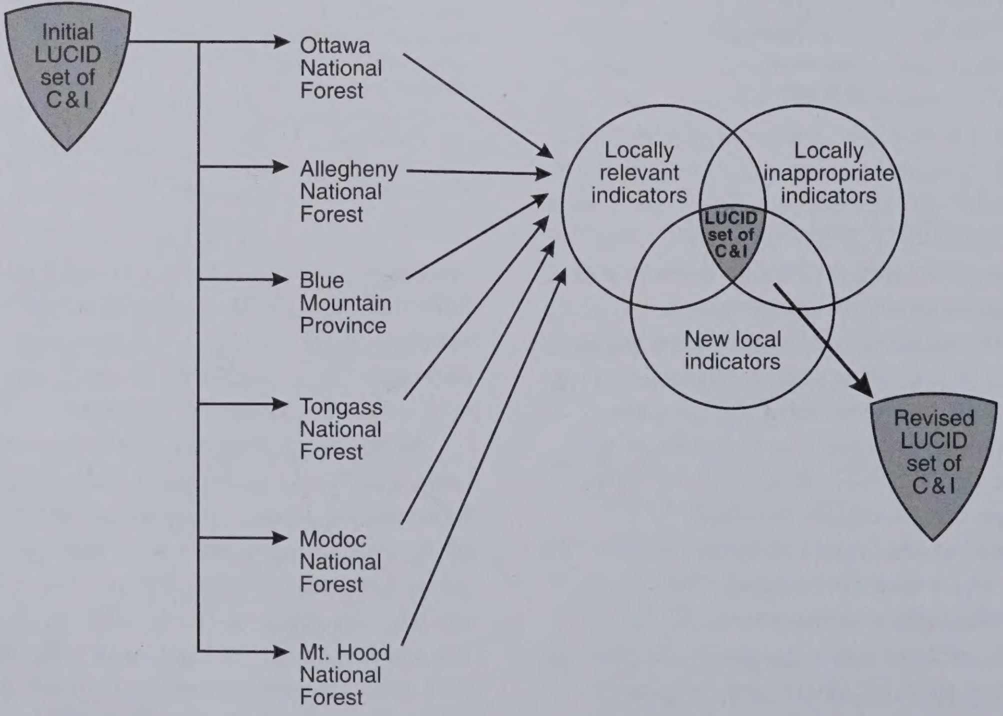


Figure 10. Testing of the Initial Suite of Criteria and Indicators

monitoring by many (e.g., CIFOR-NA; CIFOR; van Bueren 1997); but to date, few C&I initiatives had moved the process to this level. Most C&I programs compare indicators against trend data. While trend data provide one way of looking at indicator progress by itself, those trend data alone do not provide sufficient information on the desired sustainability target and the progress towards it. The core team and forest teams discussed reference values (originally referred to as "standards") together to describe their purpose, the needed elements of a reference value, possible sources for reference values, and the mechanism for developing them within the software tools developed to guide the analysis (see discussion below). However, forest teams had to do the majority of their development and exploration of reference values independently (for a detailed discussion on reference values see Chapter 10).

Although a standardized meta-data database was provided for teams to record the elements, definitions, explanations, rationale for changes, and other details, most teams did not work within the database but used instead a variety of other forms to record this information. Some forests provided meta-data in several different forms from word documents, to word tables, to spreadsheets.

Data Collection

A key conclusion of the CIFOR-NA test, and of many other C&I development projects, is that development and testing of a suite of C&I are not complete until the indicators are populated with data and analysis has been conducted. The LUCID forest teams were tasked with acquiring data for two primary reasons: 1) to adequately test the C&I; and 2) to produce a preliminary set of results in order to provide a basis by which to judge the utility of FMU-scale sustainability monitoring. There was no expectation that during a pilot test process that the forest teams would have access to all of the necessary and desired data. If this had been the case, the teams would have selected indicators and measures only on the basis of what was available and not on the basis of what was needed to adequately monitor for sustainability. The quantity and quality of the data that the forest teams were able to use varied based on the indicators and measures tested on that pilot, the availability of existing data, and the resources available to find and organize the data. Data sources varied from forest-specific data sets, to national data sets (NRIS, FIA, etc.), to data from other institutions and organizations including universities, census data, and counties. The analytical and modeling approach used in the LUCID Project permitted the presence of missing data and also allowed forest teams to document when proxy measures were used as a substitute for the preferred measure.

Integration and Analysis of Results: Conceptual and Analytical Modeling Tools

With few exceptions most C&I initiatives at all scales report results for individual indicators organized typically by criterion. Attempts to examine interactions of the results of the suite of C&I theoretically, conceptually, or analytically have been limited. The LUCID Project approach, based on the recommendations from the CIFOR-NA test, was to accomplish the following:

- Advance the state of knowledge and mechanisms by which to integrate the suite of FMU-scale C&I;
- Provide tools to guide and organize the development and testing of the C&I;
- Provide tools to guide and analyze the C&I within a systems context;
- Document the decisions made in this analysis; and
- Display the results in ways that would provide meaning to managers.

To accomplish this, the core team selected an expert-based modeling software program that would provide a mechanism to synthesize the , ecological, social, and economic systems that are the framework for the C&I set, and that would allow components of those systems to be pulled apart and regrouped in various ways to provide insights into the key management issues facing the pilot forests. The model selected was NetWeaver and its spatial extension, GeoNetWeaver (developed specifically for the LUCID Project), developed by Mike Saunders and Bruce Miller at Pennsylvania State University.

The modeling software was used in two primary stages in the LUCID Project. At the mid-point in the tests, a conceptual model was built of the principles, criteria, indicators, and measures (see Chapter 12). Conceptual model development was iterative; and as indicators were refined and measures were developed, the model shifted. The conceptual model was very useful in capturing the complexity of the C&I hierarchy, of clarifying the spatial scales for analysis, and for forcing teams to develop specific measures. The model was less useful in building linkages across the principles but it did bring to the forefront the discussions about the need for building these linkages. Once the forest teams moved to identifying specific data elements and reference values, the model was transitioned from a conceptual to an analytical model. Spatial data were related to the NetWeaver model using the GeoNetWeaver interface and then data for each measure could be compared against the reference values. Results could be examined spatially (with a mapped display of the outputs), in tabular or statistical form, or graphically within the dependency networks of the model.

The forest teams were actively involved in the development and testing of the GeoNetWeaver software, and the tool evolved iteratively based on the recommendations of the forest teams. The development of the software and the challenges associated with learning a new program that was rapidly shifting dominated much of the latter stages of the pilot test and at times the software seemed to be the LUCID Project. Despite problems working with the software in these initial stages and some recommendations for further changes that are needed (Chapter 13), most team members think that the program has potential if used in concert with other techniques.

From an analytical perspective, NetWeaver and GeoNetWeaver provided the primary mechanism to compare and synthesize the results of the data collected for each indicator as compared to its reference values. Use and development of the software did dominate the time and agendas of the forest teams; and although they were not limited to using only these tools, most teams did not have sufficient time to explore other options. Teams noted that while the modeling programs provided an excellent way to organize the results and perform initial analysis, additional post-processing or analysis was needed to more fully analyze or present the results. A few of the forest teams did pursue some of these techniques and found that they helped provide more meaning for understanding and communicating the results and recommended these techniques as supplemental to any software models (Chapter 13).

Reporting

In addition to an evaluation of the pilot test, forest teams prepared a report that was intended to summarize, in a draft form, the results or products of an FMU-scale sustainability assessment. Although some general guidance and examples were provided to the teams, the method and approach for analyzing and reporting these preliminary sustainability assessments were left to the forest teams to develop. Consequently, the teams were involved in testing and trying various approaches to analyzing and ultimately presenting the results. The hope was that the collective experiences of the six pilots could help develop advice or models for future local-level sustainability assessments. All teams noted that their sustainability assessments were preliminary in nature; not only were necessary data unavailable and standards and selection of the C&I still developmental, but the forest teams did not have adequate time to do a full analysis and to report all of the detail that they wanted. However, the teams still explored a variety of different approaches that serve as a useful basis for discussing options.

As with the analytical portion of the project, reporting the results from sustainability monitoring seemed challenging for most forest teams. In addition to the acknowledged time limitations, many teams seemed to struggle with the concepts of synthesis and analysis and what might go in a report; and consequently, most of the reports do not present in a detailed, analytical way the key messages or results of sustainability monitoring that the forests gained.

Whether or not a separate, stand-alone report is done in the future (see Chapter 14), the value of reporting the results in some way was that it forced the teams to clarify the lessons learned and to integrate the results into messages that may be useful for management and for the public. In the future, however, the forest teams indicated that additional guidance on options for reporting and a model report or examples to guide the reporting process was desirable.

Core Team Analysis and Revision

The completion of the forest teams' components of the LUCID Project signaled the beginning of more intensive analysis and research by the core team. The results of the LUCID Project were not based on the experience of any individual pilot but rather on drawing together the experiences across the pilots.

Based on the six tests of the initial LUCID core set of C&I, the core team analyzed the results to determine if there was a common suite of C&I. The intent was not to select the C&I just because they were used by the majority of forest teams involved in the pilot but rather to work from their experiences to build a suite of C&I that might be generally applicable across the national forest systems. The core team also looked to see where common indicators and measures could not be identified and where variation at the FMU scale was necessary. This process involved compiling the six forest teams' lists of C&I and associated meta-data and conducting a number of reviews and comparisons. Where issues, such as overlap with national inventory systems, were not fully explored by the pilots, the core team did additional research to pursue these issues (the detailed process and resulting suite of C&I are discussed in Chapter 11).

Science Review

Throughout the process a number of opportunities were identified for scientific review including both formative and summary review. In addition to the researchers who worked on the LUCID core team and were involved directly in the individual pilot tests, several specialists provided input at various stages of the test. For example, early in the design of the LUCID test process, Ravi Prabhu, the CIFOR Criteria and Indicator Program Coordinator, visited with the core team and provided advice on structuring the testing process and integrating results. Similarly, during the development of the economic systems approach a review group of Forest Service economists was assembled to provide input into the initial economic systems framework.

Each of the six forest teams also had a range of science assistance from both Forest Service personnel and people outside the Forest Service.

At the completion of the pilot test portion of the project and the IMI core team analysis, a team of external reviewers from the scientific community involved in sustainability and monitoring issues was asked to individually review the final products. Specifically, these reviewers were asked to examine the following:

- The scientific adequacy of the project in addressing the original objectives;
- The subject areas within the report for clarification and further development; and
- The utility and scientific validity of the approach taken in the LUCID Project for local-level indicator development with specific attention to the areas of innovation.

Reviewers were asked to make suggestions for implementation of an FMU-type sustainability-monitoring program; to recommend areas for further development and research; and to identify the scientific limitations of the proposed FMU-scale sustainability-monitoring approach. A wide range of comments was received from the science review members and incorporated where possible in the final version of the report. (Refer to the *Science Review Supplement* located at the end of this report.)

AN INTERDISCIPLINARY APPROACH

Sustainability, as a construct, is naturally assembled from many different professional and academic disciplines. Practitioners within these disciplines frequently hold profession-based perceptions and develop unique vocabularies to express their perceptions. Resultant conceptions of sustainability are incomplete. A discipline-based approach to sustainability defines the ideas too narrowly, and that can preclude the exchange of ideas and the identification of interrelationships between indicators. Consequently, as with other ecosystem management activities, there is great value in working together in an interdisciplinary (ID) team format to develop a sustainability-monitoring program. An ID team includes both the skills and the working styles of its members. ID teams that are comprised of a broad range of different skills, but that divide work by traditional skill areas, have a limited chance at developing a truly interdisciplinary product. Like other aspects of collaboration, an interdisciplinary approach often requires a longer time commitment. Most people have been trained in discipline-based work, but specific processes and techniques are often required to engage people in truly interdisciplinary work. Being truly interdisciplinary means changing the way we organize ourselves, the ways we spend our time, and our willingness to work in areas and ways outside our expertise.

Central to the LUCID Project was developing a set of C&I structured under a framework of ecological, social, and economic systems. Both the LUCID core team and the forest teams required a mix of skills to develop the C&I. Ideally, this meant that each team would be composed of an ecologist to address the ecological systems components, a sociologist to address the social systems components, and an economist to address the economic systems components, an analyst/GIS specialist to address the data management, modeling and technical aspects, and a team leader to help coordinate and integrate across disciplines. The following sections describe the teams that were involved in the LUCID Project, their experiences and recommendations regarding team composition, and their interdisciplinary working approach.

The LUCID Core Team

The LUCID core team set the stage for the pilot process. This role included conducting the initial research, developing tools and processes for testing, serving as process guides for the forests, advising the forest teams, and analyzing and synthesizing the results from the pilots into a final report with recommendations for the future. The LUCID core team was based out of the USDA Forest Service Inventory and Monitoring Institute (IMI). Team members for the core team consisted of staff from IMI, other Forest Service personnel, and contractors with specialties in sustainability monitoring (see Appendix 8). A conscious attempt was made to build upon the experience gained from the CIFOR-NA test in Boise, Idaho by including two team members from that team.

The core team worked in a collaborative fashion throughout the process; and while we drew on our disciplinary expertise when needed, we normally worked in an interdisciplinary fashion. Throughout the test each team member developed a much better understanding of the breadth of the discipline areas and the processes involved in developing a multidiscipline sustainability-monitoring program. As a result, when a core team member was unable to attend a meeting with one of the forest teams other core team members could substitute.

LUCID Forest Teams

The initial direction given to the forest supervisors was to assemble a team of 4-6 specialists with the skills necessary to conduct a sustainability assessment, along the lines of the skill sets represented in the core team. The forest teams worked in an interdisciplinary fashion to develop and adopt a set of C&I that fit their forest conditions. They gathered data from their set of C&I and analyzed those data to gain insight into the sustainability of their pilot forest. Their ultimate responsibility was to report the results.

The forest teams revealed several insights into team composition and developed some very unique, innovative, and effective team compositions (see Table 4). Generally, forest teams had to seek expertise outside their national forests; only one of the six forest teams was composed entirely of personnel from within its forest. In one forest a regional office employee was utilized to fulfill several needs; in another a wildlife researcher from the nearby research station was utilized; and on another forest other personnel from a nearby forest were utilized to fill in gaps in skills and knowledge. Finally, two forest teams, recognizing the lack of available skills in the social and economic arenas, enlisted faculty members from nearby universities. These team members brought with them the ancillary support of graduate students who were able to fulfill a broad range of functions.

The forest teams also recognized some needs that were not obvious when the initial recommendations for team composition were provided. There was a much bigger public involvement role for the forest effort than originally anticipated, so at least half of the forest teams initially included a public affairs person. Also, all of the forest teams recognized the benefit of a sustainability assessment as either a precursor to or a monitoring component of forest planning; so many of them had representation from their forest planning staffs. Finally, two thirds of the forest teams recognized the need for GIS/database development skills up front and so included a GIS analyst on their team at the outset.

Each forest team recognized that despite the range of skills included on their team they needed

Table 4. Primary Team Composition by Source and Area of Expertise

	Ecological Sciences	Social Sciences	Economics	GIS/Data Base/ Analysis	Planning	Total Number of Team Members
Core Team	1.5	0.5	2	1.5	1	5.5
Allegheny NF						6
National Forest	1			1		
RO/FS Res.	1					
University		1	2			
Blue Mtn						5
National Forest	3	0.5	0.5	1		
RO/FS Res.						
University						
Modoc NF						3
National Forest	2	0.5	0.5			
RO/FS Res.						
University						
Mt. Hood NF						5
National Forest	2			1		
RO/FS Res.						
University		1	1			
Ottawa NF						5
National Forest	3			1	1 (economist by training)	
RO/FS Res.						
University						
Tongass NF						7
National Forest	3				1	
RO/FS Res.		.5	1	1	.5	
University						

to draw on additional resources and expertise. The teams ended up developing a "core" and a "satellite" team structure that seemed to function quite well. These satellite team members included staff from the forest, the regional offices, and research. Some of these satellite team members were very aware and involved in the LUCID Project while others were involved just on an as-needed basis and may have been able to provide assistance although they had limited involvement or knowledge of the LUCID Project.

LUCID Forest Supervisor Team

Shortly after the selection of the forest team, a LUCID forest supervisors' team (FS team) was formed. Their charge was twofold: (1) provide policy insight on sustainability monitoring and support the pilot tests; and (2) through the knowledge gained from the pilot tests help IMI evaluate the pros and cons of implementing FMU-scale sustainability monitoring.

The FS team met in person or through conference calls several times throughout the LUCID Project. They discussed the role of LUCID in national forests management and planning, shared their experiences in the pilot process, and reviewed and helped develop implementation ideas. The FS team served as a network of supervisors interested in sustainability monitoring at the local level, and a number of smaller meetings (e.g., within region) have been held among supervisors and between supervisors and other Forest Service staff as a result. The FS team has also had the opportunity to present LUCID Project updates and findings to the Chief's office in Washington, D.C. along with other WO staff.

Forest Supervisors' Perspectives: The Value of LUCID

Sustainable resource management begins at the forest level. "There is a need to know whether management actions contribute to sustainability," affirms John Schuyler, Deputy Forest Supervisor from the Blue Mountain Province in Oregon. His colleague, Wayne Chandler, Forest Supervisor from Modoc National Forest in California, adds that, "It is at the forest level that community interaction and interdependence are most intimate." Schuyler and Chandler are two of six forest supervisors who gathered at the Inventory and Monitoring Institute (IMI) in Fort Collins, Colorado, this past spring to discuss the Local Unit Criteria and Indicators Development (LUCID) project.

Ultimately, the value of LUCID will be to provide forest managers and partners with a framework that can be used to coordinate monitoring and encourage collaboration between [national forests], stakeholders, and government agencies. … John Palmer, Forest Supervisor on Allegheny National Forest in Pennsylvania, has extensive experience working with criteria and indicators. As Palmer considers LUCID and its application in the United States and in forests around the world, he predicts that, "The criteria and indicators framework will continually evolve. It takes energy. It takes time. It takes effort. We're just scraping the surface." Chandler agrees, "LUCID shows a lot of promise and will provide a common framework for forest inventory assessment and forest plan work."

Many [people] maintain that successful implementation will create better collaboration, a common language, and clear communication lines. In order for criteria and indicators to become useful tools for assessing sustainability, the LUCID participants agree that what is learned on the [forests] must be applied nationally, and even globally.

As Gary Larsen, Forest Supervisor of Mt. Hood National Forest, points out, "Americans remake new ideas as we try them on. Only after thoroughly hammering and shaping them to be useful in our own personal world do we acknowledge their merit and adopt them."

(Excerpted from Paqueo 2000)

Engaging the supervisor's directly into the LUCID Project was an important step in the testing process. The FS team members stated their concerns, requirements, and ideas for the tests; and both the core team and forest teams were able to build a linkage to the policy perspectives expressed by the supervisors. Some supervisors were very engaged throughout the LUCID Project, and their involvement made an important contribution by ensuring the test remained a priority for the team members and by helping build a stronger connection between management and planning and monitoring.

LUCID Experience on Team Composition

Issues related to team composition and the interdisciplinary approaches to sustainability monitoring were examined both by the forest teams and the core team. Some of the key issues that may be relevant for implementation are summarized here.

Leadership

Leadership was a central issue to the success of the forest teams and originated from two sources: (1) the management support that came from the Forest Leadership Team (FLT), and (2) the LUCID team leaders.

Forest Leadership Team Representatives

Forest leadership teams, along with the regional foresters, were critical in nominating their forests for participation in the LUCID Project. FLT support ensured that the appropriate personnel could be devoted to the test. FLT representatives were critical in helping set the direction for the LUCID pilot test on the forest, for helping team members maintain the LUCID Project as a priority, and for helping develop a vision of the role that sustainability monitoring could play in forest management.

---

[1] On several of the LUCID forests, a change in forest supervisors throughout the time frame of the test was a challenging factor to obtaining continuous FLT leadership and involvement in the project.

Not all forest teams were able to maintain strong involvement of their FLT representatives, due to other demands, management challenges, and personal interests[1]. However, those forest teams that had continuous and close involvement of their FLT benefited from more clearly understanding the interests and concerns of FLT; and in turn, the FLT representatives came to understand in much more detail what LUCID really was about. This mutual understanding helped guide the forest team in both process and product.

"The social and economic indicators were assigned to one team member who primarily worked independently...the social and economic work proved too large and diverse to handle comfortably and cover to the extent desired. Some attempts to enlist a stronger university or research involvement did not work out."
(Ottawa National Forest Team)

For example, Gary Larsen, Forest Supervisor of Mt. Hood National Forest, helped create the initial vision of their LUCID pilot, which in turn guided the selection of team members. He was very supportive of having his staff engage in a "learning process" about sustainability and in developing tools that would help them "tell the stories" of sustainability on Mt. Hood National Forest.

For Phyllis Green, Forest Supervisor of Ottawa National Forest, the LUCID Project provided an opportunity to develop FMU-scale sustainability monitoring that would relate strongly to the detailed ecological land classification system that the forest had developed. It further related to their ongoing forest monitoring effort and will enable forest personnel to prepare for the upcoming forest plan revision.

Even though financial support for the LUCID Project was provided from the Forest Service national budget, most teams said that it was always difficult to juggle the LUCID Project with other forest priorities and other national initiatives (e.g., Roads Analysis). A number of forest teams also noted that although there was generally good support from Forest Service management to have team members and other forest specialists involved throughout the LUCID Project, shifting forest priorities often allowed for less than full participation from both team members and other specialists. Gaining access to forest specialists was described as difficult by most teams; specialists typically had other work demands and time constraints that made them relatively inaccessible.

"The accomplishments we did make as a pilot team are testimony to each member's ability to juggle overall expectations and schedules, to their other team members' willingness to support the ever-changing time and commitment the LUCID Project would take to complete, and to leadership team support."
(Ottawa National Forest Team)

Forest Team Leaders

Managing a program that had a number of steps that occurred over a relatively long time required consistent coordination. Team leaders not only managed the communication and administrative responsibilities of the their pilot tests, they served as primary working team members as well. Since LUCID methodology evolved as the test proceeded, the team leaders needed both great flexibility and the ability to redirect and refocus the team members. As the Mt. Hood team noted, "team leader skills are critical as the 'glue', especially with a team that's spread out physically." The skill sets and actual roles that the team leaders played varied greatly and for some teams the leader took on many roles. Team leaders came from ecology, silviculture, planning, and analysis. Those who had experience working across disciplines or in other interdisciplinary functions seemed better able to coordinate the many LUCID Project tasks. In addition to fulfilling the demands of a regular team member, team leaders often served as data brokers trying to coordinate a number of specialists and experts in finding data.

As the project wound down and moved to the analysis and writing phases, many teams had difficulty in maintaining team integrity because teammates were reassigned to work on other projects. Although having a dedicated team leader to guide the project to completion was a definite benefit, the report writing was often left to the one person. One forest team noted that the lack of enough time to work on LUCID, particularly near the end, "limited our ability to pursue more in-depth considerations regarding development of indicators, standards, or the like" (Ottawa National Forest Team).

Sociological and Economic Skills

At the national forest levels, personnel with skills in the economic and sociological disciplines are in very short supply; and people with that expertise are often involved in many other projects. Finding individuals with these skills was a great challenge for the LUCID Project. Three of the forest teams were able to draw on a staff member from the participating forest or from an adjacent forest, but in all cases this one person retained primary responsibility for both the social and economic criteria and indicators, which accounted for two thirds of the indicators. One forest team was able to obtain assistance from regional office specialists although those people did not become involved until the project was fairly well established. Two forest teams took a creative approach and partnered with neighboring universities to supplement their skill sets with sociologists and economists.

Because social and economic arenas inherently cover both national forests and land ownerships outside adjoining national forests, involving external collaborators in the social and economic systems, was a practical and productive solution. There was, however, initial hesitancy in almost all cases, whether the sociology and economic skills were filled by Forest Service staff or outside participants, for other FS team members to play as strong an interdisciplinary role in the discussion of social and economic issues. This was often due to a general unfamiliarity with the disciplines but was also exacerbated with external expert team members.

Ecological Skills

The ecological skill sets of the forest team members varied greatly from team to team but in general were sufficient to draw from the more traditional strengths of the Forest Service. Most teams had the participation of terrestrial and wildlife ecologists but some involved hydrologists, while others involved soil scientists or range ecologists. Selecting team members in the ecological disciplines according to the forest-specific characteristics seems important. Several forest teams observed in retrospect that they would have liked the involvement of a fisheries or aquatic ecologist, but personnel with those skills were in very high demand or in short supply. In addition to selecting team members with the right mix of ecological disciplinary skills, having team members who have been involved in research, inventory, or monitoring of different ecological systems appeared to be beneficial. Most team members had focused their work on population or community systems, and finding people familiar with landscape systems and genetic systems were more difficult. Forest teams that were unable to find specialists in genetics to assist them ultimately did not conclude their testing of the organism criteria.

GIS/Analyst and Database Skills

When the LUCID Project was initially developed, the fundamental role that people with GIS/analyst and database management skills would have was not anticipated. Not all teams were able to find a person with the right skills who could devote enough time to the pilot test and that often left team members working in the details of computer models or databases where they were less comfortable. In cases where the individual responsible for database management and GIS/analyst duties was also performing other duties (e.g., as team leader or team member), devoting enough time to the technical requirements was typically impossible. Yet GIS/analysts who were involved as full team members (e.g., participating in all discussions in the evaluation and selection of indicators and verifiers) were not only more aware of the overall project but were able to provide input early on into the selection and design of the monitoring program; this was critical for operational success.

Public Affairs Officer (PAO)

Two teams involved their Forest's PAO early in the process. As the Modoc team noted, the PAO "played an important role in understanding local social and economic issues and in providing a link between the forest and local community groups." Although broader collaboration and public involvement was generally limited in the pilot test, in the long term the more collaborative approach necessary to successfully conduct and implement FMU-scale sustainability monitoring will necessitate the full involvement of a PAO.

Planning Skills

Several forest teams had identified members of the forest planning team in their selection of team members, and in one case the forest planner served as the team leader. Although the perspectives and skills that planning staff have were not initially identified as a prerequisite to participation, the experience suggests that involving the forest planner or other members of the planning staff was extremely beneficial and therefore strongly recommended. Planning staff had several skills that were particularly useful. From a process perspective, planning staff frequently have experience in working on issues or projects within an interdisciplinary framework. From a product perspective, planning staff can help provide a much needed concrete link between forest planning and sustainability monitoring within an adaptive management framework.

External Team Members

All but one of the LUCID teams[2] actively engaged outside experts. In most cases these external participants were Forest Service staff from other forests, from regional offices, or from research. However, two forest teams partnered with local universities to supplement the skills available within the team. In both cases involving university personnel, the FLT was interested not just in ensuring that their forest had the necessary skills to participate; but they also specifically wanted to build a collaborative partnership that might continue beyond the LUCID Project. Economics and social science faculty members, along with their graduate students from Pennsylvania State University and Portland State University, served as full team participants for the Allegheny and Mt. Hood LUCID tests, respectively. Both teams cited the following points as strong advantages for including external team members:

- Development of alternative and broader perspectives;
- Good cross-pollination of ideas;
- Good cross-discipline cooperation and information sharing;
- Access to a diversity of other specialists;
- Good focus when the team was able to meet together.

The challenges of working with team members from outside the Forest Service included:

- The need to provide a strong link to ongoing Forest Service policy;
- The need to make sure that someone within the forest can coordinate, explain, and provide available data;
- Obtaining the needed products from external collaborators working different schedules and meeting different demands.

Probably the teams' strongest recommendation was to partner the external collaborator with a Forest Service staff member. The collaborators expressed the strong desire to be more integrated into the team and to have Forest Service staff participate equally in discussions and debates and not to view the collaborators as independent experts. They felt that they learned a great deal from the full team discussions about the interpretations of theory and perspective that were necessary when making these concepts operational within a Forest Service setting.

> *"By all accounts, one of the most important products of this pilot test was assembling and operating a team of Forest Service and external scientists. The process and interaction no doubt helped improve each part of the analysis. It also resulted in adopting a larger geographical sphere of influence for the analysis that extended beyond the forest boundaries. And it introduced some university faculty and graduate students to real world dimensions of forest sustainability that may carry over to their future research and teaching...The downside of the external-internal team was the lack of continuous interaction that might have taken place with a total Forest Service team. Coordination also became more difficult due to physical locations and differences in schedules."*
> *(Mt. Hood National Forest Team)*

Size and Location of the Team

The average forest team consisted of five people although the relative amount each individual was able to work on the pilot test varied greatly. Overall, a five-person team seemed adequate for most functions if frequent use was made of forest or other specialists to provide additional information (e.g., genetics) where needed. Because of other demands on the forest, one team ended up working with a core of three team members and the workload on them was excessive. They recommended supplementing the team with additional skilled people to do the work.

---

[2] The team without formal external team membership tried to engage others but were unable to attract external participants given the relative isolation of the forest and other commitments of the available external specialists.

The geography of the forests and the fact that most teams were comprised of staff from that forest and staff from elsewhere meant that all of the teams were geographically dispersed. For some members this was as little as a two-hour drive between locations, but for most team members travel time was a half to a full day. Having a geographically dispersed team did make it difficult to meet and function in a full team setting, and most forest teams reported that they made the most progress and were forced to be more interdisciplinary when they were together. They also noted that coordination and communication across the disciplines could have been improved; they often worked independently in subteams since there was not enough time to bring the full team together to discuss issues. A geographically diverse team was not without its advantages, however. The Tongass Forest Team stated that "because the Tongass is a 17 million acre forest that varies considerably from one end to the other, it was important that there were team members with experience from all parts of the forest in order to provide a diverse, wide-ranging perspective. It would not have been possible to adequately analyze the entire forest if all of the members came from the same area."

The diversity of the forests, the desire to collaborate with other team members, and the geographic dispersion of forest staff collectively suggested that this issue will continue to confront other FMU-scale sustainability issues. Prior to engaging in such a process, the potential team members should have a specific discussion and develop strategies to overcome geographic barriers and gain the benefit from a truly interdisciplinary approach. The core team did use a number of NetMeetings with teams to address more specific issues and questions as the test progressed. This approach could have been used more frequently; however, most participants recognized that there are substantial differences between meetings mediated by technology and traditional face-to-face meetings.

Interdisciplinary Working Style

An interdisciplinary collaboration is achieved not only by selecting team members from a range of different disciplines but also through the structures and processes by which the teams work. The CIFOR-NA test differed from the LUCID Project in several ways. The team of external (not local) experts was assembled for an intensive 6-week period in one location. Although the common location and the intensive time created an easy opportunity for interdisciplinary achievement, the size of the task, the tight time frame, and the fact that most team members did not know each other prior to the test made this more difficult. While smaller work teams were developed to focus in specific areas and some broad discussions were held at the beginning of the test, the majority of the work was done individually.

The experience gained from the CIFOR-NA test influenced the design of the LUCID Project. Forest teams were comprised of local experts, while technical coordination was provided by a permanent team at IMI. The IMI core team traveled to each of the forests and worked with the teams through approximately 5, intensive, 1-week workshops. This workshop structure created a time and space where all team members were together and could work in an interdisciplinary setting. The core team also tried to develop steps in the process or tools that would encourage a continued interdisciplinary approach. For example, during the initial sessions all team members participated with the core team in a first-pass review of all indicators. This was intended both to increase each team member's familiarity with all the concepts and to build the comfort level necessary for team members to contribute on all the indicators regardless of whether they were trained in that disciplinary area.

The team composition and the workshop structure were primary mechanisms by which the interdisciplinary approach was enabled. Some team members really took up the challenge and participated fully in all discussions while others were more reluctant to get involved in topics outside their areas of expertise. Part way through the testing process, forest teams were paired up and encouraged to hold their workshops jointly. This experience was so successful in sharing ideas and experiences among the teams that the final set of workshops were held jointly as well.

Though a great deal of interdisciplinary discussion did occur in these paired workshops, most teams reported that the bulk of the truly interdisciplinary work happened during the workshops with the core team. As the process progressed and with time scarce, teams fell more and more into a "divide and conquer" behavior. They noted that this coincided with tasks that really would have benefited from a more interdisciplinary approach. Teams indicated, for example, that in the identification of data elements and in the discussion and setting of standards, interdisciplinary involvement was minimal although in retrospect they felt it was critical in these areas.

In the analysis and reporting stage of the project, and faced with tight time limitations, most teams identified one or two principal writers who drafted sections of the report. In retrospect this is one of the most critical areas for interdisciplinary involvement. Although analytical tools used in the process (e.g., NetWeaver Chapter 13) can help inform these discussions, the true synthesis of findings comes from the discussions among team members. One forest team held a briefing meeting with the FLT and others part way through the analysis and writing process, and this review meeting provided them with the opportunity to have an exploratory discussion about the preliminary results being generated and to identify areas that needed further work.

CHAPTER 5.
COLLABORATIVE APPROACHES TO SUSTAINABILITY MONITORING

BACKGROUND: THE NEED FOR MULTIPLE PERSPECTIVES 71

➠ *Introduces why the diverse values of sustainability need to be designed into a monitoring program.*

THE LUCID EXPERIENCE 72

➠ *Outlines the role of collaborative involvement during the LUCID Project.*

IMPLICATIONS 73

➠ *Discusses implications for who might be involved in FMU-scale sustainability monitoring and what their potential roles might be.*

> "No one group has the ultimate authority to define sustainability, and different individuals and organizations will continue to hold their own views on the subject... it would be useful to recognize that sustainability cannot be a purely objective concept and will require collaboration on many levels." (Farrell 1998).

BACKGROUND: THE NEED FOR MULTIPLE PERSPECTIVES

Sustainability is a social construct, a complex idea composed of many simpler ideas. Consequently, it has proven exceptionally difficult to develop a common definition; and it is likewise challenging to describe, largely because the magnitude of spatial and temporal scales and the expansiveness of involved subjects exceed comprehension. Yet sustainability can be recognized even if it cannot be defined. The quandary is how to monitor something when we don't know exactly what it is. Some people have embraced the notion of using sustainability as a values-based construct to engage people jointly in a discussion of managing natural resources. This perspective is described as: 'How can we develop a monitoring program for a broad social value if we don't include a broad range of values?'

From a process perspective a program to monitor sustainability can allow collaborators to build a common language with which to discuss the construct of sustainability. Because sustainability arises from the interaction of ecological, social, and economic systems (Chapter 2) and is monitored by measuring the state of the systems and the interactions between them, an interdisciplinary approach is indispensable. From a product perspective the sustainability monitoring program will be much richer because of the interdisciplinary nature of collaborative involvement and will be more likely to include indicators and measures of the broadest range of sustainability values and concerns.

Although almost all sustainability-monitoring initiatives have struggled with the issue of definition, most criteria and indicator (C&I) initiatives have quite readily accepted the need to take an interdisciplinary approach. There is growing experience and interest in adopting collaborative approaches to sustainability monitoring[1]. Within the Forest Service collaborative approaches have been broadly promoted as a way of doing business that fits well within ecosystem management. Task forces, resource guides, workshops, and policy directives provide advice and guidance on collaborative approaches (see for example USDA Forest Service 2001). Collaboration is also consistent with the ecosystem management basis for sustainability because "management requires working across administrative/political boundaries" (Grumbine 1994).

Collaboration can play an important role in the sustainability assessment process because it can more efficiently:

- Serve as a basis for dialogue;
- Identify all key components for monitoring;
- Set reference values;
- Access alternative sources of data;
- Expedite reporting and communicating of sustainability assessment results.

A brief summary of the collaboration experience from the LUCID Project is provided here followed by a more detailed discussion of the potential roles for collaborators with comments and perspectives from the LUCID Project results.

---

[1] An interdisciplinary and collaborative approach to sustainability monitoring differs from other monitoring programs that tend to be expert-based and disciplinary in orientation.

THE LUCID EXPERIENCE

From the outset the core team and the pilot forest teams recognized the importance of involving others in the design of a sustainability-monitoring program. Due to the limited time frame for the LUCID Project, public involvement and/or collaboration was undertaken at the discretion of the individual forest teams based on their schedules and resources. The LUCID Project coincided with several other broad public consultation efforts, such as the roadless area review, and with forest-level initiatives such as Watershed Demonstration Projects, the Northwest Plan survey and management monitoring, and ICBEMP (Interior Columbia Basin Ecosystem Management Project). Consequently, some forests felt that they were dealing with an exhausted public and thus did not engage them in a collaborative public involvement effort for LUCID. Many teams also felt that given the pilot nature of the test, the tight time frames involved, and that no decision was going to be forthcoming as a result of the test, developing a full collaborative process would be premature. Personnel at two of the participating national forests used a collaborative approach to design their forest teams, which fully involved some of their potential partners in all phases of the process (Chapter 4). But by and large, the constraints in the LUCID Project limited other involvement to less collaborative and more traditional forms of public involvement.

Three of the six national forest teams sponsored some form of public involvement during the LUCID Project, and the others had opportunities for less structured involvement. All forest teams noted that in lieu of public involvement or collaborative efforts during the test process they were able to access and utilize the results of other related public involvement initiatives including recent forest plan revision, NEPA project analysis, and issue-specific workshops (e.g., roadless reviews) to provide suggestions and ideas for the design of the monitoring program.

A Vision for Collaboration

The Vision

Collaborative stewardship is people working together, sharing knowledge and resources, to ensure sustainable ecological systems and communities.

What it is

◆ Inclusive:

It is important for the people affected by and knowledgeable of an issue or opportunity to be involved in decisions related to it. The concept of [human] community includes both communities of place and communities of interest.

◆ A way to accomplish an ecological approach to management:

It is one of the ways in which people work together where everyone has a perspective and a stake in the outcome.

◆ A shift in focus:

Instead of interests lobbying the Forest Service decision-maker, collaboration involves people discussing their interests and concerns among themselves, with the Forest Service a participant in the dialogue. It is a change to working with people instead of merely communicating to them.

◆ Relationship based:

It is the development and nurturing of long-term relationships that sustain both [human] communities and the environment instead of seeking input on proposed actions.

Report of the Collaborative Stewardship Team

www.fs.fed.us/newcentury/collaborative_stewardship.htm

IMPLICATIONS

Who Should We Collaborate With?

In seeking outside involvement in C&I development and implementation, forest teams considered a wide variety of government and nongovernment agencies and individuals. Key contacts included government agencies, at all levels, that are involved in social, economic, or ecological monitoring or management plus nongovernment organizations or industry groups involved in monitoring, certification, or sustainability issues.

Involving agencies or individuals that were currently operating monitoring programs helped expedite the design of sustainability-monitoring programs because the forest teams could draw upon their expertise concerning proven monitoring methods. Forest teams looked for opportunities to partner with other agencies that could participate in the monitoring where appropriate.

During the LUCID Project, two forest teams held more formal meetings with potential partners to initiate dialogue, to learn about other organization's and agencies' monitoring interests and programs, and to cultivate contacts with these organizations. The Ottawa Forest Team, for example, first met with county-level planners and managers and then met with other organizations involved in monitoring.

Contacting potential partners was one thing, but finding candidates to contact was another. The Blue Mountain Team found potential monitoring partners through the Blue Mountains Tri-Forest Monitoring Newsletter. The forest teams also used techniques such as forest "family meetings," bulletin boards, and websites to keep other forest staff members involved and to solicit their perspectives. The importance of developing strong and early contacts with partners in monitoring, including with internal publics, and cultivating these relationships was a key recommendation of the forest teams.

Potential Roles for the Public

C&I as a Basis for Dialogue

The forest teams all expressed the importance of more meaningful involvement of the public and the development of a dialogue about sustainability. The Modoc National Forest Team noted that "[u]sing the concept of sustainability provides a unifying framework for discussion of different management and monitoring that is potentially quite positive." In addition, the Blue Mountain Team commented that "interacting with the public about sustainability within a defined framework provides a better 'tool' because it forces individuals and groups to discuss meaningful ways to meet the needs of others. It doesn't necessarily mean all those needs will be met, but it provides a way to discuss balancing of ecosystem needs and tradeoffs in a more explicit manner. The focus has generally been on outputs or outcomes, not on systems as a whole." The forest teams noted that even from their preliminary discussions they were able to initiate a common vocabulary about sustainability. One forest team felt that the systems framework may provide "a framework to examine conflicts in resource issues and the short-term and long-term consequences and opportunity costs of different sets of choices."

Ultimately, the intent with collaborative involvement is that forest management will be enhanced from the public's knowledge of and involvement with the forest.

Identifying Key Components for Monitoring

Using the C&I hierarchy for indicator development, the selection of an indicator is both guided by the systems-oriented framework but is also separated from the decision on the desired reference value for that indicator. Consequently, it is often easier for people holding different perspectives to agree on the inclusion of an indicator to monitor. Some have approached this process from the perspective that a broad range of values (represented by indicators) that can be monitored should be included in the C&I suite. Although obviously limited by the resources available to support the monitoring, a more inclusive approach to selecting indicators and measures can accommodate a broader range of perspectives on the meanings of sustainability.

Collaborators can be involved in the process of narrowing down and selecting the key indicators to measure as well. If partners can agree in advance on the attributes of good indicators, they can often work with monitoring specialists to prioritize the indicators (Chapter 8). Partners can categorize the indicators based on the extent to which they address a broad range of perspectives. Indicators that meet the interests of a broad range of perspectives might be prioritized for inclusion. In contrast, indicators might be specifically included if they address a perspective that is not well represented with other indicators.

Collaborative involvement with partners can not only help to develop a common vocabulary by which to discuss sustainability, but partners can help identify key components or indicators to monitor. Possible approaches range from a full team approach (such as the inclusion of the university collaborators on the Mount Hood and Allegheny teams) to approaches that use information submissions to guide the development of indicators.

During a meeting with county planners and commissioners, the Ottawa Forest Team received a set of key concepts and possible indicator ideas that reflected one county's definition of sustainability. The Ottawa Team was able to use this list to determine overlap and prioritize or identify important indicators for Ottawa National Forest. Similarly, each of the Canadian Model Forests has taken a collaborative approach in its development of local-level indicators of sustainability. One model forest convened a community-visioning group representing a broad cross-section of perspectives. The group held a series of workshops to identify desires, hopes, and fears about the model forest and their associated human communities (Loucks 1999). The technical indicator working team then used these desires, hopes, and fears to develop indicators and methods of measuring those indicators that would meet the community's interests.

The challenge with selecting indicators collaboratively revolves around the same issues as indicator selection generally. Choosing a framework (a systems approach) and using it to guide the selection of indicators is not easy, but it can help ensure that the final suite of indicators represents the entirety of systems and does not over represent one component at the expense of another. Finding the best and fewest number of indicators requires careful evaluation. Narrowing down to the most discriminating indicators will probably require the inclusion of the perspectives of monitoring specialists or researchers.

A common set of indicators will provide a more consistent approach to monitoring sustainability; however, this approach may not provide enough flexibility to meaningfully involve collaborators in the development of indicators. Alternatively, the Forest Service could decide to use the suite of core indicators for measurement on national forests but engage collaborators to support a more customized monitoring process for lands outside Forest Service jurisdiction. Chapter 11 includes a discussion of the indicators most likely to be unique to the given circumstances of a forest and ripe for adaptation at the local level through collaboration.

Setting Reference Values

Most forest teams noted that the selection of specific methods to verify indicators was more of a technical task that would involve those who were knowledgeable about measurement specifics and about data availability. However, a key conclusion for all of the LUCID forest teams was the importance of collaborative involvement when reference values are set for indicators. Reference values are the targets for measuring progress towards sustainability and can come from a variety of different sources (Chapter 10). Collectively, however, these reference values represent desired future conditions about the state of the systems that are to be sustained. Although these reference values can be informed by science, the LUCID teams noted that only in a very few cases were applicable standards that fit within a sustainability context published or otherwise available. Establishing most reference values involved a great deal of professional judgment that in the long run would need public engagement and confirmation. One advantage of the analytical tools (Chapter 13) used in the LUCID Project was the ability to easily test alternative scenarios using different reference values. This process will allow scenario modeling based on different conceptions of desired future conditions. Ultimately, these reference values may need to be confirmed through forest plan revision.

Access to Alternative Data Sources

Collaborative involvement can be used specifically to acquire data from existing sources. LUCID forest teams used data from a wide variety of sources including Federal, State, and County agencies. Several forest teams noted that universities, nongovernment organizations, private landowners, and other potential collaborators had other data available that the teams simply did not have time either to pursue or to generate on their own. LUCID participants noted that greater collaboration may also have the effect of providing a data leveling function among other agencies regarding data sources. Gaining access to data from other organizations will require relationship building in advance so that these organizations are comfortable with how the data will be used and for what purposes.

CHAPTER HIGHLIGHTS

- Sustainability is a social value and as such is subject to a wide range of definitions and interpretations; involving a broad range of perspectives in discussions of sustainability is therefore necessary. The LUCID teams recognized the importance of collaborative involvement; and although time and resources were limited during the test phase, all included some aspects of public involvement and collaboration.
- Collaborative involvement in monitoring allows for developing a common language to discuss sustainability.
- Collaboration can also help in identifying key components for monitoring, in setting reference values, in accessing alternative sources of data, and in communicating the results.

Section 3:
Criteria and Indicator Results

Chapter 6. Monitoring Hierarchies: The Criteria and Indicators Approach

Clarifies the nature and value of a criteria and indicators hierarchy and describes the hierarchical framework of the LUCID Project.

Chapter 7. Development of the LUCID Systems Frameworks

Takes the theory of systems frameworks discussed in Chapter 2 and traces the evolution of the ecological, social, and economic systems frameworks within the LUCID Project.

Chapter 8. Indicators

Examines different types, characteristics, and methods for identifying indicators. Summarizes the evolution and development of indicators within each of the systems.

Chapter 9. Measures and Data Elements

Outlines the process used to develop measures and provides an overview of the measures in the LUCID Project. Discusses issues related to the availability and adequacy of protocols, data availability and quality, and the use of corporate data.

Chapter 10. Reference Values

Reviews the different types of reference values and discusses the experiences of the forest teams' work with reference values including implications for future use.

Chapter 11. A Core Suite of FMU-Scale Criteria and Indicators

Highlights the final suite of principles, criteria, indicators, and measures and provides an overview of the Resource Database that provides detailed information on each of the elements.

CHAPTER 6.
MONITORING HIERARCHIES: THE CRITERIA AND INDICATORS APPROACH

BACKGROUND: THE VALUE AND DEVELOPMENT OF CRITERIA AND INDICATOR HIERARCHICAL FRAMEWORKS 79

Clarifies the nature and value of the hierarchy for criteria and indicators.

THE LUCID EXPERIENCE: THE PRINCIPLE, CRITERION, INDICATOR, AND MEASURE HIERARCHY 80

Defines the nomenclature and components of the C&I hierarchy used in the LUCID Project and contrasts it with other C&I hierarchies.

IMPLICATIONS 83

Discusses issues of specificity and consistency and how the C&I hierarchy is implemented within a broader systems framework.

> "A hierarchical framework describes hierarchical levels…to facilitate the formulation of a set of parameters in a consistent and coherent way. It describes the function of each level as well as the common characteristics of the parameters appearing on a particular level."
> (Lammerts van Bueren and Blom 1997)

BACKGROUND: THE VALUE AND DEVELOPMENT OF CRITERIA AND INDICATOR HIERARCHICAL FRAMEWORKS

Comprehensive monitoring programs such as sustainability monitoring can be complex and the number of measures employed large. Consequently, a hierarchical structure is often used to provide a clear, consistent, graphic representation of the underlying concepts for monitoring while also showing the relationship of these concepts to what is monitored.

Criteria and indicators (C&I) represent hierarchical frameworks designed to provide a common understanding of what is meant by sustainability and to frame sustainability-monitoring programs. Because sustainability is such an abstract concept, these hierarchical frameworks are intended to break down, step by step, in a logical way the goal of sustainable forest or ecosystem management into parameters that can be monitored and assessed.

The potential value of a C&I hierarchy is threefold:

- To ensure a transparent relationship between the parameter that is being measured and the component it refers to;
- To provide an increased chance of complete coverage of all the important aspects to be monitored or assessed;
- To reduce redundancy by minimizing superfluous parameters (Lammerts van Bueren and Blom 1997).

Numerous national governments, international declarations, forest management units, and forest certifying bodies are using criteria and indicator frameworks to structure monitoring efforts. Although the term *Criteria and Indicators*, or *C&I*, is commonly used to describe the monitoring hierarchies, the definitions and interpretations of the terms and the overall hierarchies vary considerably. Some researchers have proposed the adoption of standardized terminology (see for example Lammerts van Bueren and Blom 1997) to describe C&I frameworks; however, there is still a great deal of variation in use. These differences in nomenclature can present an unnecessary stumbling block. Using clearly defined terms in a common way has great value in ensuring consistency in application and in aiding understanding; Consequently, this section provides the following information:

- Describes the overall components of C&I frameworks;
- Clarifies the differences in nomenclature to facilitate understanding;
- Explains the use and evolution of the hierarchy within the LUCID Project; and
- Explains how the monitoring hierarchy of C&I was combined with a systems approach to form a framework to guide sustainability monitoring.

Clarifying the Nomenclature of C&I Hierarchies

In their simplest form, hierarchies for sustainability monitoring are typically composed of two elemental groups, which are known as criteria and indicators (C&I). In a recent Food and Agriculture Organization compendium of C&I for sustainable forest management (FAO 2001b), the following definitions were used for C&I:

"*Criteria* define the range of forest values to be addressed and the essential elements or principles of forest management against which the sustainability of forests may be assessed. Each criterion relates to a key element of sustainability and may be described by one or more indicators.

Indicators are parameters that measure specific quantitative and qualitative attributes and help monitor trends in the sustainability of forest management over time."

Clearly defining the levels in a monitoring hierarchy is important because definitions contribute to the accurate organization of elements within a monitoring framework. The consistent and accurate use of a hierarchy has important implications when evaluating the completeness and clarity of a monitoring framework. According to the FAO (2001b) definitions, criteria reflect the theoretical underpinnings of monitoring, while indicators are the elements measured. Although the use of a simple two-level hierarchy is common in most national-level initiatives (e.g., Montreal Process, ITTO) in application many have found that having only two levels is often insufficient to organize the theoretical concepts and measures related to monitoring and so additional levels are added either formally (e.g., CIFOR, LUCID) or informally (e.g., the Montreal Process unnamed levels).

THE LUCID EXPERIENCE: THE PRINCIPLE, CRITERION, INDICATOR, AND MEASURE FRAMEWORK

Based on the recommendations of the Tropenbos Foundation and following the initial guidance of the CIFOR initiatives, the LUCID core team framed the monitoring initiative within a multilevel hierarchy. The LUCID monitoring framework was designed to meet the needs of monitoring at the forest management unit scale while also providing a generic template for the development of local-level indicators within all national forests spanning a wide range of ecological, social, and economic conditions.

Overall, our objectives in describing and delineating a precise hierarchical framework were to accomplish the following:

- Adopt specific and common terminology among LUCID forests;
- Clarify the relationship between the concept of a systems approach to sustainability and C&I (see Chapter 7);
- Develop a set of indicators that could have broad application across a range of settings;
- Remove any overt directionality implied in the phrasing of the component (criterion) and the parameter (indicator) so as not to imply a bias towards any particular set of desired systems conditions;
- Develop a set of C&I that is applicable across a broad range of ecosystems, both forested and nonforested, and socioeconomic conditions including ownership status;
- Separate the parameter of interest (the indicator) from the way that the parameter might be assessed (the verifier/measure) given that the measurement method might vary from place-to-place or from time-to-time;
- Define and distinguish between the indicator and its measurement method and the reference value used to assess the state of the indicator. This results in indicators as generic elements in the hierarchy with measurement methods and reference values adapted to the unique conditions that exist among national forests or even within an FMU.

Common Components of Criteria and Indicator Frameworks

Building on the CIFOR-NA test and the work of the Tropenbos Foundation, the LUCID Project began by using a hierarchical framework that consisted of five levels: principle, criterion, indicator, verifier, and standard (LUCID commonly referred to this as the "PCIV" framework). An important outcome was a modification and refinement of the initial definitions and names of the PCIV framework and the addition of a new level to make explicit an unnamed level used in the hierarchical framework. The final hierarchical framework consisted of six levels: principle, criterion, indicator, measure (formerly *verifie*r), data element (new optional level), and reference value (formerly *standard*) (see Figure 11, Table 5). Where possible, we tried to use common definitions of the levels of the hierarchy as clarified by the Tropenbos Foundation, but we did find a need to change the hierarchy and definitions in practical application. Each of the elements of the hierarchical framework are defined on the following pages.

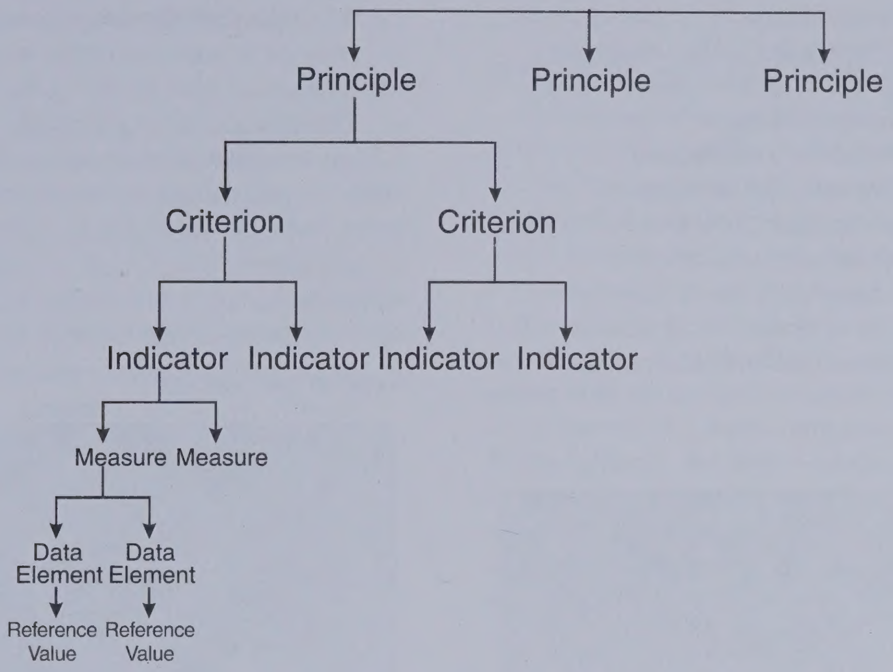


Figure 11. Schematic of LUCID Hierarchical Framework

Principles

> *"A fundamental law or rule, serving as a basis for reasoning and action."*
> *(Prabhu et al. 1999)*

Principles have the character of an objective or attitude concerning the function of the forest ecosystem or concerning a relevant aspect of the social system that interacts with the ecosystem. Principles are explicit elements of a goal. In LUCID the goal guiding the monitoring program is sustainability. The explicit elements of this goal form three principles, one each related to ecological, social, and economic systems to be monitored.

Criteria

> *"Criteria provide concrete parameters that expand and link the more abstract nonmeasurable principles of the hierarchy to more specific indicators that can be measured." (Lammerts van Bueren and Blom 1997)*

In LUCID criteria define the structural and functional components of the ecological, social, and economic systems. LUCID criteria tend to express components at a coarser level than in other C&I applications. Also, in many other C&I hierarchies criteria express a direction related to sustainability (e.g., water quality is maintained); LUCID criteria define components of systems without an implied directionality. Together, principles and criteria express the higher order theoretical sustainability constructs of the ecological, social, and economic systems.

Indicators

> *"Indicators define in a qualitative or quantitative manner specific attributes that can be measured. The language for indicators must not imply a measurement method, a specific scale, or a reference value." (Lammerts van Bueren and Blom 1997, refined for LUCID)*

In the LUCID hierarchy, the indicator level provides a generic set of assessment parameters that are broadly applicable to all national forests settings. Many monitoring programs use an unnamed level below indicators to organize subgroups of associated indicators. While subgroups of indicators can provide more specific definition to broadly worded indicators and can help organize large indicator sets into like kinds, the *ad hoc* and inconsistent use of subgroups detracts from the intent of a monitoring framework. Consequently, while the use of *subindicators* was explored in the LUCID Project, for consistency the decision was made to eliminate subindicators. As a result, however, some of the LUCID indicators encapsulate relatively broad parameters and others more specific ones.

Measures

> *"Measures provide specific details that describe the way the indicator is measured in the field and include the source of information for the indicator and the measurement method, including the form, scale, timing, and units of data that are gathered are specified." (Lammerts van Bueren and Blom 1997, refined for LUCID)*

Although the development of means to assess indicators is a necessary part of actually implementing a C&I program, relatively few initiatives have represented this stage by a hierarchical level. Both the Tropenbos Foundation and CIFOR who do represent this hierarchical level label it as a *verifier*, and the Tropenbos approach includes the concept of the reference value with the verifier. LUCID's initial hierarchical framework utilized the term *verifiers* in keeping with these other systems; but over the course of the LUCID Project, participants found the term imprecise, leading to the selection of the label *measure* for this level in the hierarchy.

In view of the fact that LUCID indicators are applicable to a wide range of ecological, social, and economic conditions found within the United States, separating measures from indicators is critical in order to permit an appropriate adaptation of measures to local conditions. This distinction means that while the basic measurement parameter (the indicator), remains constant, there is the necessary flexibility in the selection of the most feasible or appropriate measure to assess an indicator.

Data Elements (Optional)

Data elements are basic data that inform a measure. The data element may be a direct value or it may be a calculated value based on other data collected.

Based on LUCID's test implementation of C&I, it was found that measures often require the collection of multiple pieces of data. While in some cases the measure is sufficiently narrow and no data elements need be specified, in most situations LUCID forest teams found the need to specify elemental data for each measure.

Reference Values

> *"A reference value is an established standard (e.g., a legislated standard); a known scientific threshold (e.g., as reported in scientific literature); or a benchmark established through a public process, comparison with a range of variation (e.g., historic range of variation), or assessment of a trend; that can be used to evaluate a measure or data element." (Lammerts van Bueren and Blom 1997, refined for LUCID)*

The final level in the LUCID hierarchy, *reference values*, replaces the previous name *standards*. While the intent of the level remains similar, the name change avoids the use of a term that may have specific implications (*i.e.*, legislated standards). The inclusion of reference values in the C&I hierarchy means the LUCID monitoring framework contains the necessary information to assess or evaluate the parameter against a specific desired future system condition. Reference values have a one-to-one relationship with data elements or to measures if data elements are not required. A given reference value may be common across national forests or may vary within a forest (for example by watershed or vegetation community type).

Final LUCID Hierarchical Framework

Through the test implementation process conducted by the six forest teams, important elements of the C&I hierarchical framework were refined, including:

- Adoption of a systems approach conveyed through *principles* and *criteria*;

- A widely applicable C&I set through the use of *indicators* that are worded broadly to facilitate applicability across the range of settings;
- An ability to adapt C&I to local national forests conditions through the selection of appropriate *measures* and *data elements*; and
- Inclusion of the information necessary to make an assessment using *reference values*.

The components of the LUCID hierarchical framework are shown with their definitions and an example C&I set in Table 5. The hierarchical nature of the framework means that lower order components (e.g., measures, indicators, criteria) are related to higher order components in a nested system (see Figure 11). As such, principles may include several criteria; a criterion may include several indicators; indicators several measures, and so forth.

IMPLICATIONS

Specificity and Consistency

The set of rules used in the LUCID Project for common labeling of the PCIM hierarchy resulted in a list of components that are generically worded. The generic wording was perceived to be useful because we felt there was more chance that a broadly worded indicator would be applicable across a range of settings. Generic wording however runs the risk of being imprecise and susceptible to multiple interpretations.

Consequently, each component within the PCIM hierarchy has both a generically worded label and supporting documentation that provides a specific definition and description to explain it in more detail (details provided in Appendix 9 and in Chapter 11).

Table 5. Components of the LUCID Hierarchical Framework for Monitoring

Component	Definition	Example
Principle	A fundamental law or rule serving as a basis for reasoning and action. An explicit element of the sustainability goal.	P2 Ecological integrity is maintained
Criterion	A component of the structure or function of the ecological, social, or economic systems, which should be in place as a result of adherence to a principle. Criteria form the conceptual architecture of the systems under investigation.	C2.2 Landscape structure/composition
Indicator	A quantitative or qualitative parameter that can be assessed in relation to a criterion. Note that indicators have no implied direction, measurement method, spatial or temporal scale or reference value.	I2.2.2 Landscape patterns
Measure	The methodology and source of information for the indicator. The form, scale, timing, and units of data that are gathered are specified.	M2.2.2.3 Density and distribution of human developed features by use class (e.g., road density, number of road crossings, distance to human developed features)
Data Element	The elemental data that support a measure. Some measures are specific enough that the level of data element is not needed.	D2.2.2.3.1 Road density by 4th field watershed
Reference Value	The benchmark, standard, or norm against which the data are assessed. Reference values specify the range or threshold expressing the desired future systems condition over a given period.	R2.2.2.3.1 Open road density in 4th field watershed 0.7-1.7 road miles/square mile

Throughout the LUCID Project, forest teams often found that wording a PCIM component as a question was helpful in developing an explanation of what that component meant and why it was included. When sharing C&I lists with the public, care should be taken to provide the detailed definitions of the PCIM components or to reword the components in a way that is more explicit about their meaning in a given location.

When considering the PCIM hierarchy from the uppermost level that consists of three principles down to lowest levels that consist of numerous data elements and reference values, there is a significant change in character of the components. These changes can be described as a change from the following:

- Knowledge to data;
- Consistency to flexibility; and
- Breadth to specificity (see Figure 12).

The higher levels of the hierarchy are associated with higher order constructs of sustainability (knowledge), they are broadly applicable (consistency), and they are less specific (breadth). It is at the lower levels of the hierarchy that information needed to collect data is provided, and this requires flexibility in application and greater specificity to meet the needs of local conditions. The upper levels of the hierarchy, the principles and criteria, provide a common and consistent structure (or architecture) that articulates a monitoring program throughout the Forest Service.

The suite of principles and criteria developed in LUCID have utility across the range of conditions tested (Pennsylvania, Michigan, California, Oregon, Alaska). The indicators act as a bridge between the theoretical constructs provided in the principles and criteria to the indicators and their specific detail provided in measures, data elements, and reference values. Indicators provide specific direction about the ecological, social, and economic systems parameters to be monitored in broadly worded language that is relevant in most situations across the United States. The lower levels of the hierarchy (measures through reference values) are worded in sufficient detail to precisely define the parameters to be monitored.

The experience from the LUCID tests suggests that there remains, however, a need for flexibility in application whereby measures, data elements, and reference values may all be adapted to local forest conditions. We recognize, therefore, that within the PCIM hierarchy data are collected and analyzed at the lowest levels of the hierarchy, while meaning is generated through the interpretation or synthesis of results at the higher levels of the hierarchy.

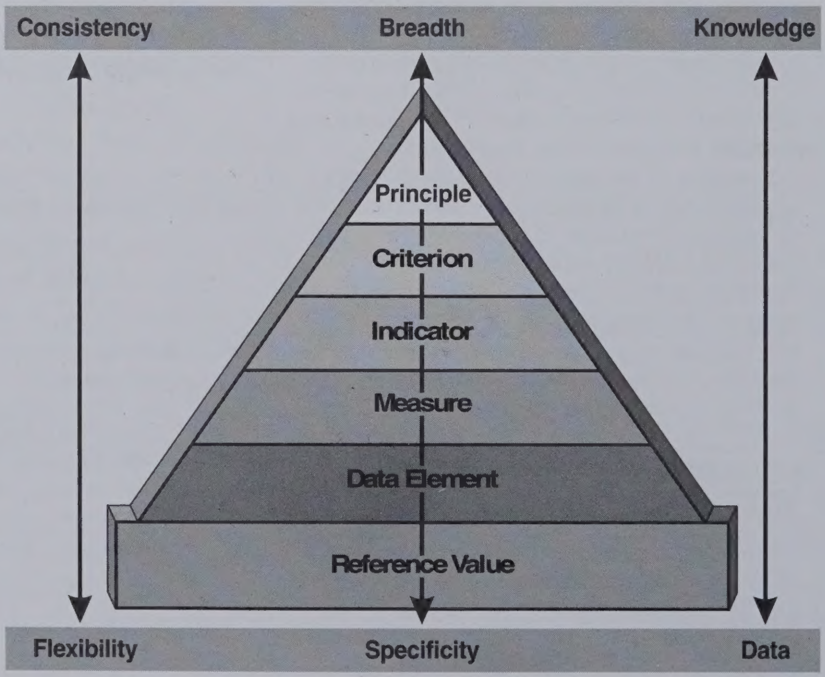


Figure 12. Dimensions of the PCIM Hierarchy

Comparisons between Criteria and Indicator Frameworks

FAO (2001b) has compiled information on ten C&I monitoring frameworks established to assess sustainable forest management. Most of these initiatives are national or multinational in scope, with only the CIFOR C&I framework directed at a local-level sustainability assessment. While each C&I initiative described is different, the use of C&I is common to all approaches. The number of levels used in the hierarchical frameworks described in the FAO (2001b) report range from two to five levels (Table 6).

Although the LUCID Project is based on a more detailed hierarchical framework with slightly different interpretations of components, making comparisons between the nomenclature and the levels is a relatively straightforward process and should not impede understanding. Regardless of the level of detail and the different nomenclature, the concept of indicators remains constant. As these are the primary components of the monitoring program and most likely to be the parameters discussed and contrasted, this is the level best suited for comparison.

Comparison between the Montreal Process C&I framework and LUCID's PCIM framework is of interest because the Montreal Process C&I is well known, and this frameworks is implemented through national-level assessments of sustainability. Although the Montreal Process framework only includes two named levels, in common practice there are additional unnamed levels and some of these parallel the LUCID PCIM framework. Within the MP nomenclature, the term *criterion* refers to a broader concept more akin to the LUCID term *principle*. The unnamed set of subcriterion (indicated in italics in the MP texts) is roughly equivalent to LUCID *criterion*. The indicator level is common to both hierarchies with a similar meaning although in some applications in the MP hierarchy the indicators included references to specific measurement approaches or reference values. In reporting (see for example USDA Forest Service 1997), measures and data elements are commonly used although they are not labeled hierarchically. Other C&I initiatives use different variations of the hierarchical levels (see Table 7).

Relationship Between the Criteria and Indicator Hierarchy and a Systems Approach: Merging Frameworks

The intent of the PCIM hierarchical framework is to clearly and consistently articulate the meanings and relationships of the various components of a sustainability-monitoring program. As described previously in Chapter 2,

Table 6. Comparison of the number of hierarchy levels and the level names used in monitoring programs to assess sustainable forest management (FAP 2001b).

Monitoring Program Name	Level 1	Level 2	Level 3	Level 4
Montreal Process on Criteria and Indicators for the Conservation and Sustainable Management of Temperate and Boreal Forests	Criterion	unnamed	Indicator	
Centre for International Forestry Research (CIFOR)	Principle	Criterion	Indicator	Verifier
African Timber Organization (ATO)	Principle	Subprinciple	Criterion	Indicator
International Tropical Timber Organization (ITTO)	Criterion	unnamed	Indicator	unnamed
The Near East Process	Criterion	unnamed	Indicator	
Lepaterique Process of Central America on Criteria and Indicators for Sustainable Forest Management	unnamed	Criterion	Indicator	unnamed
The Pan-European Forest Process on Criteria and Indicators for Sustainable Forest Management	Criterion	un-named	Indicator	unnamed
The Tarapoto Proposal of Criteria and Indicators for Sustainability of the Amazon Forest	unnamed	Criterion	Indicator	unnamed
Regional Initiative for the Development and Implementation of National Level Criteria and Indicators for the Sustainable Management of Dry Forests in Asia	Criterion	Indicator		
The Dry-Zone Africa Process on Criteria and Indicators for Sustainable Forest Management	Criterion	Indicator	unnamed	

Table 7. Nomenclature Comparison Between Montreal Process and LUCID C&I Frameworks

Level	Montreal Process	LUCID
1	Criterion	Principle
2	*Unnamed (italics level)*	Criterion
3	Indicator	Indicator
4	*Unspecified*	Measure
5	*Unspecified*	Data Element
6	*Not included*	Reference Value

the LUCID Project adopted a systems approach to guide the initial development of C&I for sustainability monitoring and this approach is a bit different than most other C&I initiatives. The systems approach is based on the concept that sustainability is an emergent property of systems and that sustainability is understood by monitoring for the contexts, rather than the outputs, of systems. By definition then, C&I developed in the LUCID Project represents elements of the systems we are studying (i.e., the ecological, social, and economic systems) and these elements are understood by examining the way in which they interact with other elements of systems. In the context of the LUCID tests, the ecological, social, and economic systems have a hierarchical architecture that is defined by principles and criteria. The PCIM framework is built on the systems approach (see Chapter 7) thereby yielding a hierarchical framework that is systems based.

Although it is relatively easy to crosswalk the nomenclature between the different C&I hierarchies, significant differences may exist between different C&I initiatives that are not apparent by simply examining nomenclature. For example, the Montreal Process framework is a hybrid based on largely issues-based and goal-based approaches to monitoring with some parallels to a systems approach to monitoring within the ecological sphere. Here is the crux: the use of the terms *principles* and *criteria* within the LUCID C&I are roughly akin to the Montreal Process *criterion* and the informal *subcriterion*, but their meanings are very different. Criteria in the Montreal Process framework describe issues or topics while in LUCID the criteria form the conceptual architecture of the systems under investigation.

Differences in C&I hierarchies and approaches ultimately lead to differences in the way monitoring data are analyzed and presented. In the MP C&I for example, analysis and presentation of results are organized within criterion (representing issues or topics), based on an indicator-by-indicator assessment. The MP hierarchical framework is not meant to explicitly convey meaning about the relationships among indicators or criteria. Within the LUCID Project the criterion and principles together describe the system; thus, analysis of indicators within the LUCID context helps describe the status of a higher order concept.

CHAPTER HIGHLIGHTS

- C&I hierarchies can help ensure transparency between parameters and concepts, increase the chance of complete coverage of important aspects of the monitoring program for sustainability, and reduce redundancy.
- The LUCID Project used a multilevel hierarchy including principles, criteria, indicators, measures, data elements, and their associated reference values in the monitoring hierarchy.
- In the context of the LUCID tests, the ecological, social, and economic systems have a hierarchical architecture that is defined by principles and criteria. The PCIM framework is based on systems theory thereby establishing a hierarchical systems-based framework.
- Names of monitoring elements (e.g., indicators) are not sufficient to communicate their complexity so additional information such as definitions and explanations are needed. For the LUCID Project this information can be found in the accompanying resource database (Appendix 9).
- Moving from the uppermost levels of the hierarchy (principles) to the lowest levels (reference values), the hierarchy is arrayed on three dimensions: breadth to specificity, knowledge to data, and consistency to flexibility.
- Within the LUCID Project the principles and criteria together describe the system; thus, analysis of indicators within the LUCID context helps describe the status of a higher order concept.
- Within the PCIM hierarchy data are collected and analyzed at the lowest levels of the hierarchy while meaning is generated through the interpretation or synthesis of results at the higher levels of the hierarchy.

CHAPTER 7.

DEVELOPMENT OF THE LUCID SYSTEMS FRAMEWORKS

BACKGROUND: THE VALUE OF A SYSTEMS FRAMEWORK 91

➔ *Recapitulates the benefits of a systems framework to guide the development of a monitoring program.*

THE PROCESS: DEVELOPMENT AND REVISION OF THE SYSTEMS FRAMEWORKS 92

➔ *Reviews the process used to develop and revise the systems frameworks by the forest teams.*

LUCID ECOLOGICAL SYSTEMS FRAMEWORK 93

➔ *Discusses the adaptations made by the forest teams to the original ecological systems framework and presents the final framework.*

LUCID SOCIAL SYSTEMS FRAMEWORK 96

➔ *Discusses the adaptations made by the forest teams to the original social systems framework and presents the final framework.*

LUCID ECONOMIC SYSTEMS FRAMEWORK 104

➔ *Discusses the adaptations made by the forest teams to the original economic systems framework and presents the final framework and indicators.*

> Sustainability may be best achieved not by sustaining the outputs of systems but by sustaining the contexts, the fundamental systems, which sustain us. The structures and functions that comprise ecological, economic, and social systems are fundamental system properties and by definition they are the criteria that describe the kinds of systems.

BACKGROUND: THE VALUE OF A SYSTEMS FRAMEWORK

Sustainability relies upon the integrity of the structural components and functional (process) interactions characteristic of the ecological, social, and economic systems that sustain us. An implication of using a systems approach is that an important foundation task in the development of C&I is attaining an understanding of the systems to be monitored. When the components of the systems have been outlined, the selection of specific indicators of the systems can then proceed.

The systems approach to sustainability monitoring is intended to provide a definition of the ecological, social, and economic systems based on the most up-to-date theories of the components and organization of these systems. Within the context of the LUCID Project, the systems frameworks are also intended to be applicable across all national forests (within their broader contexts) and must therefore capture a wide range of conditions or expressions of the social, ecological and economic systems present within the United States.

Complex systems theory has been rigorously applied to ecological systems and within the bounds of ecological sustainability is relatively well understood (see for example Allen and Hoekstra 1992, Flood and Carson 1993, Kay and Foster 1999, and Sterman 2000). A systems approach to studying social and economic systems is less common, however, and applications to sustainability more limited. Consequently, it has been more challenging to develop systems-based social and economic frameworks that provide a foundation for assessing sustainability at the FMU scale.

The systems approach is a key aspect in the LUCID Project and different than the approach other C&I frameworks and most Forest Service monitoring programs have taken. A key element of LUCID was to develop, test, and refine the utility and applicability of a systems framework approach in sustainability monitoring. LUCID participants found that the systems framework provided a new "lens" by which to conceptually and practically view the topic of sustainability. A systems framework had several distinct purposes including:

- Providing an approach to communicate that sustainability is more than the sum of the individual elements (components/parameters) that are monitored;
- Providing a strong theoretical, science-based link to understanding sustainability;
- Refining the description of elements for monitoring; and
- Developing a more meaningful method for synthesizing and analyzing results to understand the state of systems.

In addition to the benefits a systems framework offered, LUCID participants noted that a systems approach also helped conceptually in the following:

- Thinking through and refining descriptions of the systems to be monitored, i.e., it provided a key learning mechanism to understand how components are interrelated;
- Helping to identify and understand critical elements for sustainability monitoring.

This chapter provides a brief overview of the approach used to develop and refine the systems frameworks and then describes and discusses each of the ecological, social, and economic systems frameworks as they evolved through the LUCID Project.

THE PROCESS: DEVELOPMENT AND REVISION OF THE SYSTEMS FRAMEWORKS

The CIFOR-NA test of C&I served as the basic foundation for the LUCID Project. During CIFOR-NA, team members were charged with screening hundreds of indicators to select those most applicable in the North American context. The result was a set of four principles, 16 criteria and 54 indicators that covered ecological, economic, managerial, social, and institutional components. The CIFOR-NA test did not, however, explicitly structure this information within a systems framework. At the outset of the LUCID Project, the core team built on the recommendations of the CIFOR-NA test and intentionally started with the development of a systems framework to guide the selection of indicators.

Initial Development of the Systems Frameworks

Initial systems-based frameworks were constructed by the LUCID core team to serve as the foundation for selecting indicators. The systems frameworks, expressed through the principles and criteria along with an initial core set of associated indicators, were provided to each of the LUCID forest teams.

In their development, testing, and revision of C&I, LUCID forest teams were asked to maintain a systems-based approach although they could propose changes to and modifications of the way in which systems were defined (i.e., modifying the principles and criteria). At the conclusion of the forest team's work, the core team examined the changes and extent of overlap between the forests and proposed a revised set of systems frameworks. The final systems framework developed by the LUCID Project underwent considerable scrutiny and refinement, particularly for the social and economic principles, as a result of the testing process.

The LUCID Project defined three complex and interrelated systems that formed the contexts within which to examine sustainability: the ecological system, the social system, and the economic system. Although three distinct frameworks were developed, one for each of these complex systems, we recognize that only when these systems are considered together can we speak of the complete set of structural components and functional interactions that make up sustainability (see Figure 13). In addition, we recognize that the way we have bounded these systems is somewhat arbitrary—a reality inherent in conceptual models. For example, the ecological system model used in LUCID is a composite of multiple systems including, organism systems, landscape systems, population systems, and ecosystems. LUCID also uses two distinct models, an economic systems model and a social systems model, to assess the broader socioeconomic system. We recognize that these are artificial distinctions, and that economic systems are in fact a component of broader social systems. However, we found utility in distinguishing between social and economic systems because these systems tend to be separated within the organizational structures of the Forest Service, the disciplinary training of individuals in these fields are distinct, and the world views of these systems are often different.

Unfortunately, while we implicitly understand that these three systems are strongly interconnected, there currently is no unified systems theory that provides an integrated model of the ecological, social, and economic systems (Woodley et al. 2000). Nonetheless, we found that the explicit use of systems models was extremely useful as a learning tool to examine sustainability and as a way of framing the development of indicators and analysis approaches that was a significant improvement on our understanding of sustainability.

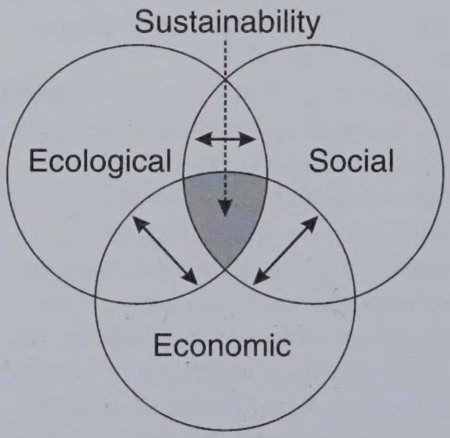


Figure 13. Sustainability is a product of the components and interactions between the three systems.

Forest Team Testing of the Core Set of Principles and Criteria

Within the PCIM hierarchy used to organize the LUCID monitoring framework, each of the three complex systems constitutes a top-level guiding principle to assess sustainability.

As a part of the test process, each of the participating forests was presented with the concepts of the systems approach to sustainability monitoring; and they were provided with draft frameworks of the ecological, social, and economic systems. Based on the actions of the forest teams it is apparent that in order to achieve a working understanding of these concepts it was essential for some forest teams to dismantle and rebuild the system frameworks. In some cases the original core system framework reemerged from this exercise. In other cases new frameworks were created and these ideas were used in the development of the final system frameworks.

The examination of systems frameworks translated into examining the principles and criteria. Apart from minor wording changes, none of the forest teams changed the PCIM principles. The forest teams did make the following types of changes to the initial core frameworks:

1. Simple changes to the nomenclature that did not change the intent of criteria in the core frameworks;
2. Combining of criteria with other existing criteria or with new criteria;
3. Revising the concept of a criterion downward and creating it as an indicator;
4. Expanding existing criteria to broaden the intent of the initial core criteria;
5. Adding new criteria; and
6. Deleting core criteria.

Besides changing the names and organization of criteria, forest teams documented the rationale for their changes and the relationship of the criteria to understanding the system and to sustainability. The process of documenting and justifying helped build an understanding of the important structural and functional aspects of sustainability and clarify how things are related. Because the application of systems theory is more common to ecological than social and economic systems, the chapter is organized to present the ecological system first so that it can serve as a conceptual foundation for the other two.

LUCID ECOLOGICAL SYSTEM FRAMEWORK

Consistent with CIFOR-NA, the ecological systems principle for the LUCID Project was labeled as "maintenance of ecosystem integrity."

The choice of the word *maintenance* could be perceived as problematic if it is interpreted narrowly. This might suggest that what is being ecological integrity was an appropriate goal statement for sustainability.

Some of the LUCID forest teams proposed slightly different wording for the principle, for example Ecological Well Being (in order to be parallel with the other principles); but the original wording remained the same at the end.

Kinds of Ecological Systems

The LUCID ecological system framework was conceived from the structures and functions of different ecological system types. The kinds of ecological systems considered in the LUCID Project included organism, population, ecosystem, community, landscape, and biome. Within the scientific literature different names can be used for these systems and additional types of systems may be considered particularly as spatial scale changes.

Ecosystem

Ecosystems are defined by fluxes in energy and matter. Ecosystem structures include such things as organisms (carbon storage) and soil (nutrient storage). Ecosystem functions include such things as erosion/sedimentation, nutrient cycling, and production/decomposition of organic matter. The specific measures of ecosystems vary depending upon the type of ecosystem structure or process addressed. Monitoring of ecosystems can be used to address issues about watershed productivity, sedimentation, soil erosion, some measures of biological diversity, and nutrient cycling.

Community

Plant and animal communities are defined by the kinds of organisms that they contain and the functions such as competition, predation, and mutualism that define interactions between organisms in the assemblage. Community systems are used to address issues about biotic diversity and old seral stages.

Population

Plant and animal populations are defined by structures such as occurrence, density, and age structure and by processes such as regeneration and movement. Populations are used to address issues related to threatened and endangered species, viability, game species harvests, and indicator species habitat relationships.

Landscape

Landscapes are defined by the size, shape, and distribution of pattern in the environment. Processes that influence those patterns include natural phenomena and human-related activities that alter the size, shape and distribution of land patterns. Landscape systems are used to address issues related to land-use zoning, distribution of plant and animal community seral stages, natural disturbance and vegetation management actions (e.g., clear-cuts, selection cuts, prescribed burning, wilderness protection, or range allotment grazing use allowances).

Organism

Organism systems are defined by individual organism structure and function (anatomy and physiology). Organism structures include plant and animal cell types (phloem/xylem, muscle/ lung/bone) and processes such as respiration, reproduction, and growth. Issues that might be addressed by organism systems include air pollution effects on vegetation and chemical effects on reproduction or genetic diversity. In the LUCID Project we limited our focus to issues of genetics; and as a result, throughout the testing process we identified organism systems as "genetics."

Biome

Biome systems are assemblages of plants, animals, soils, and physiography defined largely by geology and climatic processes. Issues that might be addressed by biome systems include wildlife species that require a very large home range such as lynx and goshawk, and vegetation management issues in coastal temperate rainforest, tall-, mid- and short-grass prairie, or shrublands such as sagebrush steppe. Although some components of biome systems are included in the LUCID Project, it was felt that most of the issues associated with biome systems (within a national forests context), are more appropriately addressed in regional or national sustainability monitoring initiatives.

The core team chose to select a minimum but critical number of kinds of systems concentrating on landscapes, organisms, populations, and ecosystems although components of community systems are included within ecosystem and population systems and some aspects of biomes are included in landscape systems.

The names of the kinds of systems use wording that is indicative of the kind of system itself and does not infer a given habitat (e.g., whereas in forestry the terms *site* and *stand* are commonly used, these terms are not easily transferred to nonforest environments and they do not represent generic terms defining a biological kind of system organization for structure or function).

Structures and Processes of Systems

Structure[1], composition[2] and function[3] are fundamental properties that can be used to examine each kind of ecological system (e.g., biome, landscape, ecosystem). By definition, they are the **criteria** that describe the ecological systems (Hoekstra et al. n.d.). Yet ecological systems have numerous structures and processes that could be considered key determinants of sustainability. As it would be too exhaustive to focus on all of these structures and processes, LUCID identified those C&I that were considered most likely to provide a timely, accurate and cost-effective determination of sustainability and which provided insight into the interactions between systems. Within the LUCID ecological system framework the landscape, ecosystem, population, and organism systems are examined in terms of their structural and functional components. Because of the considerable similarity between structure and composition, these were grouped in the framework (Figure 14).

---

[1] The physical arrangement of the various components.

[2] The specific elements that make up an interacting system (i.e., plant and animal species, microorganisms, soil type, landform, and climate regimes.)

[3] The major processes of ecological systems that regulate or influence the structure and composition, including nutrient cycles, energy flows, trophic levels, disturbances, hydrologic cycles, and weathering processes.

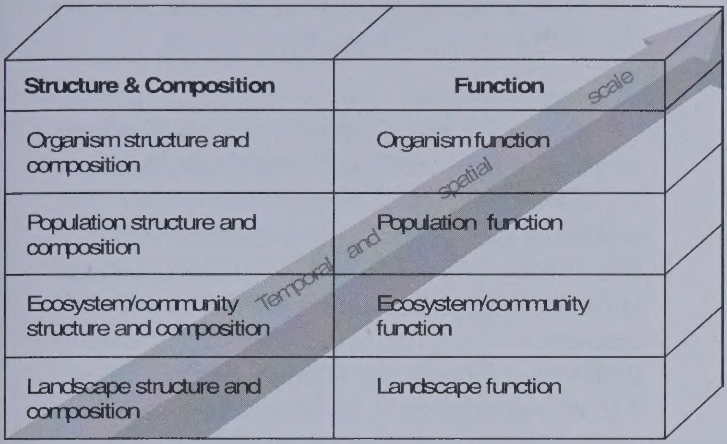

Structure & Composition
Function
Organism structure and composition
Organism function
Population structure and composition
Population function
Ecosystem/community structure and composition
Ecosystem/community function
Landscape structure and composition
Landscape function
Temporal and spatial scale

Figure 14. LUCID Ecological Systems Framework: The eight criteria are the result of the combination of the kind of system with the structure and functions of systems.

The Spatial Dimension

It is important to recognize that although the systems (organism to landscape) are often considered in our everyday language to have an imbedded spatial scale of small to large, this is not a valid science-based assumption (Allen and Hoekstra 1992). For example, although organisms might be considered small, the transfer of genes often occurs at large spatial scales and this transfer is crucial to the survival of mammals that have large home ranges. Alternatively, landscapes (i.e., patterns of distribution of structure and function components) can be either spatially large or quite small; for example, assemblages of ecosystems may exist on a single rotting log. The challenge lies in the fact that our common use of the words (particularly *landscape*) has often taken on a specific spatial implication. In the LUCID ecological framework, we have tried to separate the kind of system (organism-landscape) from the spatial dimension. Notwithstanding this, the spatial dimension should be considered within each kind of system. For example when considering landscape function and specifically disturbances, small spatial-scale disturbances and large spatial-scale disturbances should be evaluated. Consequently, the third major dimension of the ecological framework is spatial scale. The intention is that within each criterion, the ecological system should be measured at a broad range of spatial scales.

LUCID Forest Team Adaptation of the Ecological System Framework

The core ecological system framework underwent a limited amount of revision by five of the six LUCID forest teams (see Table 8). Strong internal consistency in the ecological systems framework is probably a result of relatively high familiarity with the basic components (e.g., structure and function of ecological systems) of a complex systems approach. Some minor changes were suggested. The Modoc Team for example, found utility in distinguishing between indicators of composition versus indicators of structure for some kinds of systems. The Mt. Hood Team eliminated the organism structure criterion from their framework because they found that all of the organism indicators they included were best categorized as indicators of organism structure.

Adopting a systems framework is not only useful as a foundation for developing criteria and indicators of sustainability but is also a conceptual framework to guide synthesis and analysis. To date the limiting factor in most C&I initiatives

Table 8. Comparison of Ecological Criteria Between LUCID Core and LUCID Forest Teams

Core Criteria Set	Criteria Adopted by LUCID Project Forests*				
	Allegheny	Blue Mts.	Modoc	Mt. Hood	Ottawa
Landscape Structure	≡	≡	≡ Landscape Composition	≡	≡
Landscape Function	≡	≡	≡	≡	≡
Ecosystem Structure	≡	≡	≡ Ecosystem Composition	≡	≡
Ecosystem Function	≡	≡	≡	≡	≡
Population Structure	≡	≡	≡	≡	≡
Population Function	≡	≡	≡	≡	≡
Organism Structure	≡	≡	≡ Organism Composition	Deleted from framework	≡
Organism Function	≡	≡	≡	≡	≡

≡ Equivalent wording/concept used by each test forest

* The ecological framework and criteria used by the Tongass National Forest was substantially different and so is not used in this table

(Chapter 12) is that the results and analysis of C&I monitoring are limited to an indicator-by-indicator basis alone. In this context the indicators have value only as data and are not truly indicators of integrative concepts. Development and analysis of C&I within a systems context provide a structure and context for exploring the interrelationships and emergent properties of systems.

The Final LUCID Ecological Systems Framework

The experience of the LUCID forest teams in working with the ecological systems framework suggested that although there were variations in how forest teams categorized specific indicators (see Chapter 8) the original framework had great value. Consequently, the final LUCID ecological systems framework remains unchanged from the original.

LUCID SOCIAL SYSTEM FRAMEWORK

Human systems, meaning various components of culture and society, differ tremendously in their very nature from ecological systems. While from an ecological perspective humans are simply another species that exists in the natural world, this simplistic view denies the rich expressiveness of human cognitive powers and social organization. As a result, human society derives from a very different set of organizing principles than natural systems. A framework for social sustainability must acknowledge the structures and functions of human systems that span a continuum from meeting basic needs for sustenance to accommodating transcendental endeavors. Particular attention must be paid to those aspects that involve how humans interact with natural systems and how we value the ecological systems (Hoekstra et al. n.d.).

An Alternative Approach to the Ecological Principle

In contrast to the other five forest teams, the Tongass Team took a quite different approach to the ecological principle. One of the common foundations for the LUCID Projects was the intent to use a systems-approach to understanding sustainability. Although the Tongass Team deviated from the systems-approach the result was a useful experiment to try and understand an alternative framework. The Tongass Forest Team developed an ecological framework that was a hybrid of an ecoregional approach and a resource or component-based approach. Their ecological principle contained six ecological criteria including: High-elevation Ecosystem; the Productive Forest Ecosystem; the Scrub Forest and Wetland Ecosystem; the River and Stream Ecosystem; the Lake Ecosystem; and the Saltwater Shoreline Ecosystem. The names and distinctions between these ecosystems did not follow a conventional ecological land classification or land type association approach but rather used a blend of popularized descriptions for ecosystem types and resource/component approaches (e.g., "productive forests"). The Tongass Team indicated in their evaluation that they felt their approach to the ecological principle using a partial ecoregional approach would be useful because:

- They could generate criteria that related to people's specific interests ("Often a user group is interested in either fish, or wildlife, or soils, or timber, or nonconsumptive recreation") and to management's specific interests ("Even Forest Service managers … can think at any one time on only one resource issue e.g., water quality, or vegetation, or wildlife, or fish, etc.") and
- The criteria should be "oriented around the major resource issues."

The Tongass experience provides many useful lessons in probing the relationship between the larger systems approach and the specifics of ecosystems. The larger ecological system consists of a number of kinds of systems including landscapes, populations, ecosystems, and organisms. Focusing on ecosystems alone will limit the choice of indicators of structures and functions that represent the entirety of the ecological system. If the framework is organized only around ecosystems, the other aspects of ecological systems are inappropriately associated. The result is the nested and nonnested systems are combined only within a model that contains nested systems. The resulting synthesis or analysis between the ecosystem-based criteria is built on a model of interrelationships that don't work that way. If the approach blends ecosystems with resource uses or components (e.g., lakes, productive forests) then the interrelationships, functional relationships, and emergent qualities of systems will be lost. The resource or use-oriented approach is also limiting since it treats ecological components as separate, a concept that is inconsistent with ecosystem management thinking.

The Relationship Between Social Systems and Sustainability

Attempts to establish key indicators within the context of identifying the critical structures and functions of social systems have been limited. Beyond the approach of a simple listing of data needs, a few attempts have been made to identify conceptual frameworks to address social sustainability (Table 9).

Within the Forest Service many frameworks or approaches to social issues acknowledge a broad range of social values from economic values to recreation, aesthetics, and public participation. Some find that making a connection between the Forest Service and the broader issues of social well-being is tenuous. The challenge is twofold: 1) distinguishing between broader social goals and sustainability, and 2) identifying what aspects of sustainability the FMU should be focusing on.

Is Well-Being Part of Sustainability?

Tainter (2001) posits that "[c]onceptualizing sustainability in terms of human well-being potentially opens Pandora's box." Such concepts, Tainter writes, may be desirable goals of human society but "may appear to some observers to have little to do with sustainability."

More restrictive definitions of supply-side approaches to social values that would parallel the above perspective might suggest that the responsibility of national forests (and the FMU in broader application) is limited to maintaining the physical context (e.g., an ecologically healthy forest system, clean water, a consistent supply of material for resource production) for people to express or attain value from. This perspective implies that there is a difference between desirability and sustainability but, as discussed in Chapter 1, identifying a thing called *sustainability* in absence of a discussion of human values (including desires) for many is problematic.

Table 9. Summary of Components of Social Sustainability Conceptual Frameworks

Well-Being and Needs of Forest Dwellers (Colfer et al. 2001)	**Sustainable Forest Communities** (Tainter 2001)	**Social Subsystems of Human Ecosystem Model** (Machlis et al. 1994)	**Indicator Matrix for Community Sustainability** (Beckley & Burkosky 1999)	**Community Capacity** (Doak & Kusel 1997)
Security and sufficiency of access to resources now and in the future	The social and economic structures that promote sustainability are maintained	Social institutions (e.g., health, justice, faith, commerce..)	Employment, income, and economic profile	Physical capital
Economic opportunity	The social and economic processes that promote sustainability are maintained	Social cycles (e.g., physiological, individual, institutional, environmental)	Population	Human capital
Decision-making opportunity	Interaction between social and ecological systems promotes community sustainability	Social order (e.g., personal identities, norms, hierarchies)	Education	Social capital
Heritage and identity			Health	
Justice			Social pathologies	
Health and safety			Community cohesion	
			Women	
			Race	
			Decision making	
			Natural resource use	

The broad concept of social (and economic) sustainability is not new to national forest management. National forests have long been involved in understanding the well-being of communities that are connected to Forest Service-administered lands. Indeed, the well-being of communities of interest and communities of place have been important factors in the formation of numerous policies. The concept of stability, including economic, community, and industry stability has been reflected in policies and laws such as sustained yield, nondeclining flows of timber and maintaining long-term productivity (e.g., NFMA 1976, MUSYA 1960). Likewise, the Forest Service has had a continued role in community development (e.g., Rural Community Assistance Act).

The Forest Services roles in issues associated with social systems has revolved around considering relevant social and economic information and analysis; providing opportunities for public participation, stewardship, and collaboration; and most directly through the provision of a broad range of direct consumptive uses, direct and indirect nonconsumptive uses, and intangible benefits (e.g., environmental services). These products, services, and other benefits are the means by which individuals, communities, and economies define and sustain themselves.

If we believe that human well-being including aspects of cultural and spiritual values, health and safety, education, and others are important parts of sustainability, the focus then becomes one of trying to determine which of these aspects are related to the sustainability issues we should consider assessing within an FMU-scale monitoring program examining national forests within their environs.

What is the Relationship Between the FMU and Social Sustainability?

Within developed nations economic dependency on forested systems is, on the whole weaker as economic systems diversify. This is particularly so for national forests that are only a small part of the land base in a region and an often shrinking part of a community economy. The result is that social values, and social systems, are influenced or controlled by factors well beyond a national forests. With respect to the broader aspects of social well-being (beyond economics), the lack of daily connections between forests and communities more characteristic in developing nations (e.g., where people rely on forests for food and shelter) means that the ties between people and forests are less concrete and have shifted to less tangible elements.

Some resource managers and researchers question whether national forests managers should therefore be concerned with social well-being dimensions. Much of this difference revolves around a debate over whether management effort (be that monitoring or physical projects) implies responsibility with the accompanying concerns of control (e.g., what role does the national forests have on other lands) and culpability (e.g., if the Forest Service is engaged in community capacity building/diversification initiatives is it culpable when community economies fail?). We have had the question posed to us as: If I monitor community capacity because I know I need to understand what is going on in the community that affects or is affected by the forest, people may assume as a manager I am responsible for fixing community capacity and I can’t do that.

Others advocate that public land managers have a responsibility to create, support or facilitate processes or functions—in social sciences they are typically referred to as “institutional arrangements”—to assist communities (in the broadest definition of the term) in expressing or achieving social benefit from forests. These include institutional arrangements to facilitate collaboration and stewardship opportunities for participating in community capacity building projects, among others.

The Initial LUCID Social Systems Framework

The initial social principle was worded as “social values related to the forest are maintained.” During the course of the LUCID Project, wording of the social principle changed. The first modification was the removal of the phrase *related to the forest*. This phrase was initially included to indicate that the focus was not on the wider sphere of the entire social system as much of the social system has little relationship or effect on the sustainability of national forests in their broader environs. However, the phrase was removed early in the study as it was felt that the use of the term *forest* was too limiting and might not include the range of forested and non-forested environments that were being discussed and included in the LUCID pilots. The term *maintenance* was also problematic for some as it implied stasis. Forest teams suggested a number of changes with the most commonality being *social well being,* a goal consistent with other sustainability initiatives. The concern of identifying what aspects of social well being we are trying to sustain and determining whether or not they are truly related to the sustainability of the national forests in its broader environs remains and is discussed in more detail in this section of the chapter.

Monitoring social sustainability revolves around first determining the kind of social system to be assessed. The kinds of social systems included place-based communities (e.g., counties, cities) and interest-based communities (e.g., groups of people who shared similar perspectives such as ranchers or environmentalists). It was clear that there was a mix of nested and nonnested hierarchies within the kinds of social systems. Consequently, criteria were not identified specific to each kind of social system; but rather, indicators were intended to be measured across a range of kinds of systems. For example, *access* indicators were equally relevant to place-based and interest-based communities.

An initial attempt was made to develop the social system framework based on an approach similar to the ecological systems framework whereby kinds of systems were identified and then considered in terms of structures and functions. We found, however, that the range of social values, and consequently indicators considered important to include in a monitoring program, could not be as easily classified into system structures and functions. Therefore, structure and function were not explicit components of the initial social system framework. These concepts continued to be considered, however, in the selection of indicators and measures. As a result, the social indicators provided to the forest teams in the initial core set were not as well developed and differentiated. This resulted in more substantial modification through the teams' work of the core set of social indicators to more accurately reflect the dimensions of the social system.

This initial social framework was characterized by a vertical dimension with two kinds of social systems or social groups that have an interest or stake in sustainability (Figure 15). The first kind of system—communities of place—refers to social groups that may be described in spatial ways: local communities versus communities of nonlocal people. The second kind of system—communities of interest—refers to social groups that are better described by a set of common interests: people with an ecological preservation interest versus a resource-harvesting interest. These two systems are nonnested as different groups of local people, for example, may have different sets of interest. Given the overlapping nature of different social groups within this dimension, no attempt was made to subdivide the indicators into interest groups or by specific spatial scales. This dimension of the framework did serve, however, as a reminder that

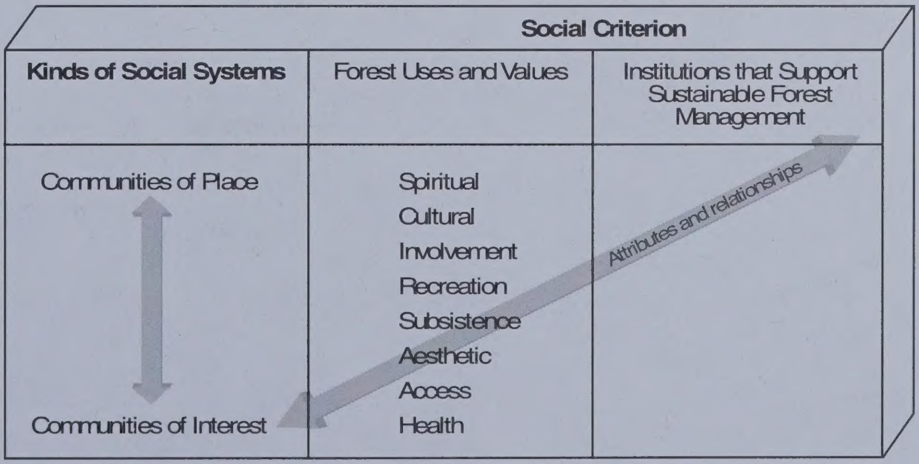


Figure 15. The Initial LUCID Core Social System Framework

criteria, indicators, and measures should consider the full range of social groupings based on considerations of both communities of place and communities of interest.

The initial social system framework was also characterized by a horizontal axis that was included the uses or values that people hold or express with respect to the forest (e.g., spiritual, aesthetic, recreational, and health values). These social values served as the criteria to organize LUCID's initial set of core social indicators. Institutions or social structures that enabled people to express these different kinds of social values (e.g., public participation processes or stewardship groups) were typically embedded or nested within these different values.

As our exploration of systems theory progressed through activities of the LUCID Project and in order to more accurately explain the social system model, the LUCID core team later divided the horizontal axis into two sections, uses/values and institutions (Figure 15).

The third axis (see diagonal Figure 15) was meant to emphasize the importance not just of measuring the quantity of physical attributes or structures (e.g., recreation user days, number of campgrounds, number of public meetings) but also the quality of the attribute or event (e.g., satisfaction with recreation use, perception of value of stewardship opportunity). For example, within the forest value called *access* indicators might be developed to monitor both physical access and perceived access.

The initial social framework used in LUCID was less developed than the economic and ecological system frameworks, and this lead to some difficulties when working with test forests. The initial social framework did not, for example, adequately explain and convey social sustainability in a systems framework. However, the initial framework was useful in beginning the discussions of social sustainability; and not surprisingly, it underwent significant changes as

Rationale for Social Systems Modifications: Mt. Hood National Forest

The criteria, indicators and [measures] for the social systems developed here reflect a theoretic position. Social systems produce the values, the institutions and processes that determine the governance of the forest system. This approach requires both an interpretive and structural sociological stance. In social sciences the orientation that informs this work best is reflected in new institutionalism or new-structuralism.

The criteria, indicators, and verifiers for the social system were selected to provide a conceptual and management framework.

- One set of indicators reflects collaborative stewardship, a process which the USDA Forest Service and others believe increases the likelihood of sustainability.
- A second set of indicators falls under the criteria of civic capacity and reflects the condition of (human) communities and the ability of those communities to respond to external and internal change (shocks).
- A third set of indicators attends to the matter of institutions and the adequacy of institutional arrangements. Institutions are the taken-for-granted conventions of social life that provide the deep structure for social processes. Social scientists have long been concerned about institutions and institutional effects. We have only recently begun to focus on the adequacy of institutions for sustainability.
- A fourth set of indicators captures the current status of social and cultural values. These are things people care about, both those values expressed in discourse and in policy making and those values deeply embedded in the fabric of social life. What these are and how we capture them is the subject of much debate and effort.
- A fifth set of indicators captures the status of community livability within the forest system. Livable communities as an approach to determining social well-being has old roots in social science and public practice and new life in current initiatives to direct attention to the importance of natural conditions in community life.

Taken together, collaborative stewardship, civic capacity, institutional adequacy, social and cultural values, and community livability provide a way to conceive of, manage, and monitor the social subsystems for sustainability.

(Source: Abridged from Mt. Hood National Forest Team) the LUCID participants collectively debated issues that included:

- What social values are related to the national forests?
- Whose values count?
- What are the critical structures and functions of social systems?

LUCID Forest Team Adaptation of the Social Framework

Although all LUCID forest teams maintained the one broad social principle, several of the teams proposed significant modifications to the framework through changes to the criteria. Table 10 presents a summary comparison of the social criteria including the initial core set. Criteria that contain similar concepts are included on the same row of the table for ease in understanding. There is general similarity between the first seven concepts although the original criteria were not viewed as useful for organizing for understanding social systems.

Several LUCID teams proposed useful modifications and additions to the framework. In general, forest teams proposed significant expansions to the concepts included within the social framework. These move beyond the properties or structures of the forest for meeting social values to include some of the broader aspects of social well-being. They also focus more on the functional or dynamic aspects of

Table 10. Comparison of Social Criteria between Initial LUCID Core and LUCID Forest Teams

Original LUCID CORE	Tongass	Ottawa	Modoc	Mt. Hood	Blue Mountains	Allegheny
Involvement values	Involvement Traditional ecological knowledge	Involvement values	Public involvement	Collaborative Stewardship		Involvement in national forest management and decisionmaking.
Access	Access	Land ownership, access and value	Access			Access to forest resources
Forest-based human health values	Forest-based human health values	Forest-based human health values (all forests/owners)	Forest-based human health and safety values		Health, safety, and services	Human health and safety
Spiritual and cultural values	Spiritual and cultural values	Spiritual and cultural values and uses	Spiritual and cultural values--sense of place	Social and cultural values	Community and cultural identity	Spiritual and cultural values
Recreational values	Recreation	Recreation, tourism, and education opportunities	Recreational values Education programs	*Social and cultural values**	Educational, cultural, and recreational opportunities and values	Recreational, tourism, and educational opportunities
Noneconomic gathering values	Spiritual self-fulfillment and gathering			*Social and cultural values*		Nonmarket gathering
Aesthetic values	Aesthetic values	Aesthetic values	Aesthetic values	*Social and cultural values*		
Other criterion with no LUCID Core equivalent		Legal and institutional framework within the region (all forestry agencies)	Equity	Institutional adequacy Community livability Community resilience	Cohesion and conflict Population	Environmental justice

* The Mt. Hood identified one very broad criterion--social and cultural values--that included components similar to several other forests' criteria.

monitoring the existence and adequacy of the institutional arrangements that some of the major processes by which people work towards social well-being. For example, the Mt. Hood Forest Team proposed some significant changes that expanded greatly upon the institutional and functional aspects of social systems. Criteria included in the Mt. Hood set of C&I included collaborative stewardship (an expanded conception of the involvement criteria), institutional adequacy, community resiliency, and community livability. Also important were the concepts of equity and environmental justice expressed by the Modoc and Allegheny Forest Teams, respectively.

The Final LUCID Social System Framework

The LUCID forest teams made some significant revisions to the social system framework that helped move it more in line with a systems approach to assessing sustainability. team representatives were given the opportunity to review this revised social system framework that incorporated most of the significant criterion changes proposed by other teams. Each forest's original indicators were placed within this revised framework and with some minor modifications there was relatively good fit.

The final social system framework has a relatively similar architecture to the economic and ecological frameworks with a typology of systems on one axis and criteria for the various components of these systems on a second axis (Figure 16). The criteria arising from this framework could not easily be organized into a structure-and-function framework; however, these concepts were considered in the selection of indicators and measures. The final social system framework includes those more traditional social values or opportunities for monitoring (e.g., recreation and aesthetics) but also includes those functions that drive social sustainability including the institutional and community structures, collaborative approaches that create a flow of information and knowledge, and the equitability of management.

The criteria used in the social system framework are described below.

Collaborative Stewardship

Collaborative stewardship is the opportunity to have one's values, attitudes, and beliefs heard and considered in national forests decisionmaking and the ability to participate in consultative and stewardship actions. Collaboration is the forum for identifying issues associated with the stewardship of national forests and for facilitating the flow of information and knowledge. Collaborative stewardship is used to address the public's concerns and desires about national forests management.

Collaborative stewardship implies a more open management and planning model than the traditional top-down and technocratic approaches of the past. This is based on the premise that national forests are a public resource that should

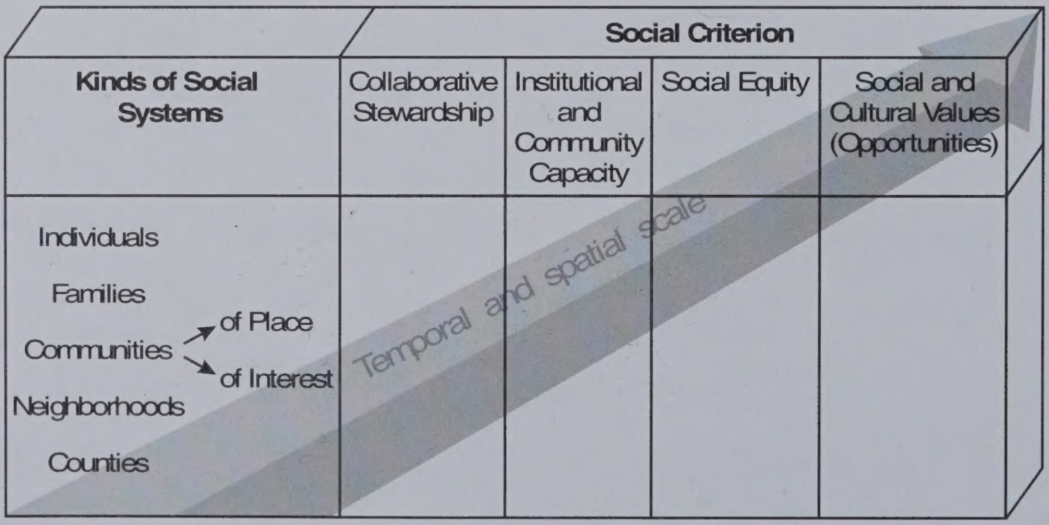

Social Criterion
Kinds of Social Systems
Collaborative Stewardship
Institutional and Community Capacity
Social Equity
Social and Cultural Values (Opportunities)
Individuals
Families
Communities
of Place
of Interest
Neighborhoods
Counties
Temporal and spatial scale

Figure 16. The Final LUCID Core Social System Framework

be managed for and by the public to the extent practicable. Chief among these ideas is that concerned stakeholders have a right to participate in open and meaningful public participation processes in order to influence management. Ultimately, sustainability is related to the extent to which public values are respected and incorporated into forest management activities. Planning processes must be simple, integrated within and between agencies, and provide transparent, easy-to-understand access and involvement. It's important to note, however, that simply having more public meetings does not equate with better involvement. Indeed, it is quality not necessarily quantity that is important. For example, participant groups must feel respected and empowered and the process should be inclusive.

Collaborative stewardship is also important to sustainability from a broad social equity context. As Gregerson et al. (1998) note, "[A]ctive participation of stakeholders in management decisions becomes an essential ingredient in a process that has no definable result [given the lack of a clear end-state of sustainability] and has to depend on stakeholder consensus to determine the path and direction of change in forest management."

Institutional and Community Capacity

Capacity and resiliency are the ability of communities or institutions to mobilize their members and collectively respond to change to create and take advantage of opportunities; and to meet the needs of residents, diversely defined (Kusel 1996). Capacity and resiliency can be used to address issues such as organization, leadership, economic and social diversity, community assistance needs, and community health.

Forests have an important role to play in community capacity since they contribute to the physical capital (tangible elements) and the social capital (by forming an opportunity or discussion point for networks of social relationships) to members of the community. Forests should support healthy communities through contributions to community capacity and well-being but in order to ensure that forests are sustainable, communities will need to directly contribute from a stewardship perspective.

Institutional capacity addresses the adequacy of institutional arrangements. Institutions are the taken-for-granted conventions of social life that provide the deep structure for social processes. Institutions describe the way people interact with one another and with the environment, and to a great extent they are the means used to solve problems and to govern use. Formal institutions include the administrative structures of the Forest Service, its plans, and its processes. Institutions typically critiqued as not responsive to the requirements of ecosystem management and sustainability include those that are insular, hierarchical, output-oriented and turf-protective (Wallace et al. 1996).

Consequently, institutions with the capacity to respond to the requirements of sustainability and ecosystem management are often best described as those that are both complex and adaptive instead of hierarchical and rigid and ones in which policy and information flows in both directions.

Social Equity

The social equity criterion reflects inter- and intragenerational considerations of the distribution of the costs and benefits of sustainability. Equity issues include worker and public health and safety, disabled access, environmental justice, and civil rights. There is substantial overlap between this criterion and the economic criterion "trade and distributional equity."

Equity has to do with recognition not only at a broad level of inter- and intragenerational considerations but of the rights and needs of minority, disenfranchised, or nonmainstream groups or individuals of all kinds. Because of the variety of groups and programs as well as the importance of the concepts of inter- and intragenerational equity, this seemed to be an important category to separate out.

This criterion is based on a number of premises. Colfer et al. (1995) note for example, that 1) people are more likely to manifest stewardship towards forests from which they derive benefit; and 2) people tend to be more willing to sacrifice immediate gain from activities that may degrade resources where they are certain that their children will benefit. Other components that relate to this criterion are the notions of fairness and justice. While both terms, like sustainability, mean very different things to very different people, they imply that resources, or costs and benefits, are distributed in an equitable way.

Social and Cultural Values Opportunity Spectrum

Social and cultural opportunities include considerations of access, recreation and aesthetics, education, tourism, spiritual, cultural, and historical opportunities. Social and cultural opportunities can be used to address issues such as preferences, demographic trends, land-use patterns, and social and cultural history or sense of place associated with the national forests. Some of these components are described here as examples.

- Forests and rangelands provide opportunities for noneconomic gathering of timber and nontimber products such as firewood, Christmas trees, berries, floral greens, other plant materials, and poles. These gathering or subsistence activities (Native American or otherwise) are often part of the culture of place that develops and becomes a traditional use of the forest.
- Visual landscape retention is important to maintaining both tourism and recreation opportunities. In addition, visual landscape retention is important to nonrecreational, quality of life dimensions.
- Educational forums that encourage and solicit feedback and value local resource information and participation are more likely to inspire collaboration and thus good integrated stewardship of the forest.
- Federal sponsorship of resource programs is another avenue for resource education and training while addressing resource employment in rural communities at the same time.
- Tourism and recreation opportunities are important to sustainability of quality of life dimensions.

A Need for Further Development

We recognized that there is a continued need for work in this area, specifically including framing social values within a systems perspective; identifying the bounds of monitoring social sustainability within a Forest Service approach; identifying indicators of the fundamental components of the structure and functions of the kinds of social systems; and developing measures that assess both the quantity of the activity or structure but also the quality and associated perception issues. More than in any of the other areas, we found that within the social principle there was much more variability from forest to forest in the indicators and measures to be monitored. This suggests greater flexibility in selection and adaptation of social indicators and measures and the need for concerted efforts from specialists to assist in the development of improved measurement protocols (Chapter 9).

LUCID ECONOMIC FRAMEWORK

In wording quite similar to other sets of C&I (e.g., CIFOR-NA), the economic principle was initially labeled as "yield and production of goods and services." Discussions throughout the LUCID Project and suggestions by some of the forest teams contributed to the final wording: "economic well-being." This change was perceived as conceptually important since it was broader and more inclusive of concepts of equity and efficiency in addition to the production aspects.

Kinds of economic systems include individual producers and consumers, firms, industries, communities, regions, states, and nations. Because the LUCID Project worked at the spatial scale of a national forests, the focus was concentrated on individual, firm/industry, and community systems. Similar to social and ecological systems, an assessment of the sustainability of economic systems includes both structure and function considerations. The economic systems framework underwent some modification based on the experience of the LUCID forest teams. Consequently, this section outlines the initial framework, the experience of the forest teams, and the final resulting framework.

At a broad conceptual level understanding the economic systems framework is based on a series of assumptions related to economic sustainability (see Table 11) including the following:

- Production of goods and services should not exceed the growing stock, that is, goods and services should be produced from the interest and not the capital.
- Although natural capital is the primary source of capital typically referred to when discussing sustainability, human (e.g., labor) and built capital are also of interest.

- Sustainability is not just about producing goods and services within the limits of the interest versus capital context; it is also about who gets what and who pays—the equity issue.
- Intergenerational equity requires that the needs of the present be met without compromising the ability of future generations to meet their own needs. This temporal concept encompasses concerns about long-term productivity, maintenance of ecological integrity, and making investments in natural capital.
- Intragenerational equity connotes that all individuals of the present generation have an equal right to benefit from the use, conservation, and preservation of resources. This is particularly true in the case where the resource, the national forests, is a public resource held in trust for the public. This could include many of the criteria and indicators dealing with income distribution and employment levels, access issues, and democratic participation processes.

Initial Economic Systems Framework

The economic systems framework designed initially to guide the development of the LUCID core set of C&I is similar to the ecological and social frameworks in that the various components comprising the system are considered at a variety of inherent kinds of organization. Although economic and social systems are often described in an integrated manner (i.e., socioeconomics), for the purposes of the initial LUCID C&I a separate set of economic C&I was developed for the sake of clarity and to be consistent with current measures used by the Forest Service for describing and organizing economic data.

The initial LUCID core economic framework was designed to have three primary criteria located on the horizontal axis (Figure 17). Each criterion is defined as follows:

1. **Wealth and Capital Accumulation**. Asset maintenance and investment in productivity-enhancing activities such as investments in human, manufactured, natural, social, institutional, and financial resources. These could be called "endowments" or "investments."
2. **Production and Consumption.** This criterion focuses primarily on the production of resources including both market and nonmarket goods and services.
3. **Trade and Distribution.** Inter- and intragenerational distribution of resources among economic actors, income distribution over time and space, and the structure and "balance" of trade. This is commonly referred to as the "equity" criterion.

These three criteria include the components of structure and function, but they are not as clearly delineated as in the ecological systems framework. Instead, the criteria represent fundamental tenants of sustainability as they relate to the stock and flow of resources. These three criteria are examined across a range of economic system types from the individual through the community. Other economic system types, such as economic regions or states, are best suited for inclusion at regional or national scales of monitoring.

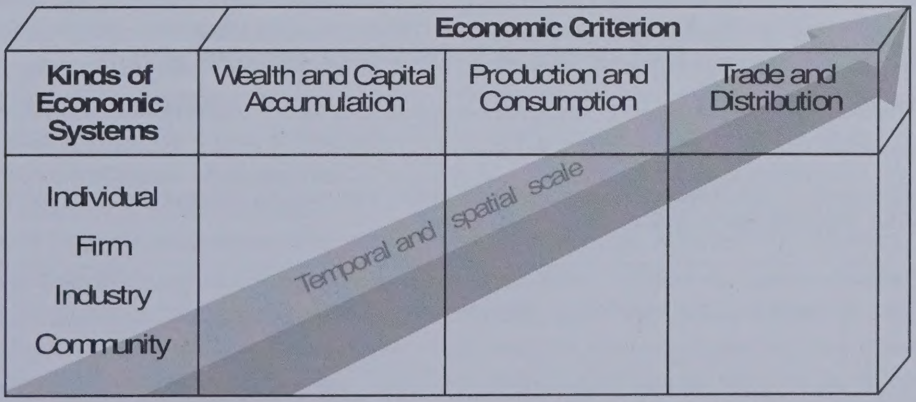

Economic Criterion
Kinds of Economic Systems
Wealth and Capital Accumulation
Production and Consumption
Trade and Distribution
Individual
Firm
Industry
Community
Temporal and spatial scale

Figure 17. The Initial LUCID Core Economic System Framework

Table 11. Some Socioeconomic Components of Sustainability

Intergenerational Equity: The term *sustainable development* was popularized by the World Commission on Environment and Development (1987) as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." A foremost characteristic of this definition is the concept of intergenerational equity, which embraces the notion that the needs of future generations are as important as the needs of the current generation. This term encompasses concerns about long-term productivity, maintenance of ecological integrity, and making investments in natural capital.

Intragenerational Equity: All individuals of the present generation have an equal right to benefit from the use of resources. This form of equity has two important components: social equity and geographical equity. "Social equity" refers to the fair distribution of the benefits and costs of natural resource use and environmental protection, taking account of such basic human needs as food, shelter, employment, public facilities and services. To many, social equity in the context of sustainability also means the improvement of equity in a broader sense, for example, more equitable distribution of income, and the elimination of discrimination. The second essential component of intra-generational equity is "*geographical equity*". This term describes the undesirability of achieving economic growth, or a higher quality of life, in one community at the expense of environmental degradation in another. They contend that this type of development is inequitable unless some form of reparation or compensation takes place between the communities. Geographical equity also implies that sustainable communities support global sustainability by minimizing their contribution to global environmental problems, such as global warming and depletion of the ozone layer. Sample questions include:

- Are local people involved in decisionmaking?
- Is there an equitable and positive rent share to all participants?
- Is there transparent allocation of rights or concessions?

Minimal Impact on the Environment: This term implies that waste discharges of all types (including emissions to the air, water effluents, contaminants of land and biota, and the disposal of solid waste) should not exceed the assimilative capacity of the natural environment, where "assimilative capacity" refers to the capacity of physical, biochemical, and geochemical processes in the ecosystem to decompose and render inert certain types of waste products. Impacts due to development and management practices should also be minimal so that habitat and natural ecosystem functions are preserved as much as possible.

Living off the Interest of Renewable Resources: Sustainability means that the depletion rates for renewable resources, such as timber and fisheries, should not exceed the regenerative capacity of the natural system that produces them. Sample questions include:

- Is there a sustained flow of environmental services and products?
- Are we living off the interest of renewable resources?
- Are investments made in the natural capital?

Carrying Capacity: The concepts of "minimum impact" and "'living off the interest" make up "carrying capacity," which has been defined as " the maximum rate of resource consumption and waste discharge that can be sustained indefinitely in a given region without progressively impairing the functional integrity and productive activity of relevant ecosystems" (Rees 1992).

Community Capacity: The collective ability of residents to respond (the communal response) to external and internal stresses; to create and take advantage of opportunities; and to meet the needs of residents, diversely defined. Community capacity includes consideration of issues such as:

- The state of the physical capital (the physical elements and resources in a community and financial capital);
- The state of human capital (the skills, education, experiences, and general abilities of residents); and
- The state of social capital (the ability and willingness of residents to work together for community goals).

Minimal Use of Nonrenewable Resources: Consumption of nonrenewable resources is unsustainable because the resources will eventually run out. Therefore, the emphasis must be on minimizing their use, using them as efficiently as possible, through reduction, reuse, and recycling, and by seeking renewable resource substitutes.

Efficiency: Increased efficiency in the consumption of resources reduces the need to harvest or extract additional resources.

Long-Term Economic Development: Enduring economic vitality is an essential component of sustainability. This condition is also frequently described as economic "prosperity."

Diversity: Diversity in the economic, biological, and cultural elements of an economic system may help to decrease its fragility thereby increasing its ability to adapt to change and perturbations.

Subsidiarity in Organization: Decisionmaking in society should be located at the lowest appropriate level. Decentralization should prevail so that decisions can be made by and for the communities and individuals most affected, with higher level organizations being "subsidiary" to lower ones. Sample questions include: - Is decision-making effected at the lowest possible level? - Is there an increasing flow of information between local and management? - Do communities participate in making the management decision?
Externalities: Ecosystems provide many ecological services in the production of goods and services including assimilation of pollutants or the provision of clean water. Typically, ecosystem charges are external to the decision maker or manager; and as they are unpriced, they are not part of the decision. The issue of externalities refers to the practice or the tendency to ignore the entire costs associated with the production of goods and services.
Resiliency: The ability to return to the original form or elasticity. Sample questions include: - Is the community resilient to changes and fluctuations? - Is the economy diverse? - Is population age distribution stable? - Is the physical infrastructure of communities diverse, being maintained, or extended?
Trade Balance: The ratio of imports to exports. Sample questions include: - Is there a positive economic trade balance? - If the trade balance is positive, is it positive because capital stocks are being depleted? - If the trade balance is positive, is it positive because human capital is being depleted or imported?
Capital Substitution: The exchange or transfer of one form of capital for another. Sample questions include: - Is built capital a substitute for natural capital? - Is this substitution efficient? - Is the decision (substitution) irreversible?
Human Well Being: An individual's well-being extends to his or her physical, social, and mental conditions. Health and education, by developing human potential, contribute to individual well-being, which also requires the satisfaction of basic physical and economic needs. Sample questions include: - Is the ratio of property value to local income stable? - Are a diverse array of human opportunities being provided for?
Precautionary Management: In the face of risk and uncertainty, be cautious in managing natural environments.

Adapted from: Woodley et al. 2000, Doak and Kusel 1997.

LUCID Forest Team Adaptation of the Economic System Framework

LUCID forest teams spent a great deal of time discussing the merits of the economic systems framework. Although the fundamental tenants of sustainability from an economic perspective were broadly accepted, determining the scope of the economic framework was a challenge. Similar to the social system framework, for some, trying to identify or isolate those portions of economic systems that were related to, or more directly affected by, national forests management was a challenge. As economies have become more diversified, the more direct or at least obvious ties between the economies of traditionally forest-dependent economies and the national forests system have weakened.

As discussions and debate evolved, most LUCID forest teams ended up deconstructing the economic systems framework and then reconstructed frameworks that were fairly similar (with some noted improvements) to the initial LUCID framework (Table 12). More significant change and evolution occurred in organizing and selecting indicators to address key components and processes of the economic criterion and these are discussed in the next chapter.

At the criterion level most of the changes were to the names of the criteria; and in a number of cases, one criterion was split into two. A new criterion, "efficiency," was added explicitly by only one forest team, but this criterion contained aspects that were common and important to many of the other teams' work at the indicator level. The LUCID forest teams also highlighted the

Table 12. Comparison of Economic Criteria Between LUCID Core and LUCID Forest Teams

Initial LUCID Core Criteria	Allegheny	Blue Mts	Modoc	Mt. Hood	Ottawa	Tongass
Wealth and capital	Capital and wealth	Land, labor and capital	Wealth and capital	Sustain minimum capital stocks	Regional wealth: land, labor, and capital	Forest capital stocks
Production and consumption	Production and use	Production and consumption from NFS lands	Production and consumption	Deliver market or market-related goods and services Supply other goods and services	Production and consumption from the Ottawa	Flows of forest goods and services
Trade and distribution	Income and employment Benefits distribution	Distribution Economic trade	Economic trade and distribution	Seek benefit and cost distributional equity Maintain trade balance	Economic trade Economic distribution	
New	Production efficiency					Economic health of forest communities

importance of including social or human capital in the consideration of wealth and capital.

Perhaps the most important differences between the approaches taken by some of the forests were in how they framed the criteria based on the kinds of systems of interest. Given the challenges that forest teams faced in discussing the bounds of the economic system, this is not surprising. The initial LUCID core economic criteria were not bound to any specific kind of system (individual vs. community) or to a geographic area but were worded broadly enough that they could be addressed across individual to community kinds of systems. The Ottawa Forest Team focused their examination of wealth and capital more specifically on a regional economic system. Three of the teams (Blue Mountains., Ottawa, Tongass) focused the examination of the production of goods and services specifically to the national forests lands.

The Final LUCID Economic System Framework

Unlike ecological systems, examples of a system approach to assessing economic systems, particularly with respect to sustainability, are relatively limited. The development of an economic systems framework applicable to FMU-scale sustainability monitoring went through a number of steps in the LUCID process from initial design, to review by a group of peer economists, to application and modification through the LUCID forest tests. The result of the LUCID forest tests was not only a revision of the criterion but also a more thorough understanding of the rationale behind the economic systems components (Figure 18).

Structure (Stock) Components

Capital and wealth. Natural capital is the endowment that ecological systems generate as diverse streams of products and services over time. The degree and distribution of changes between components of the land base and the stewardship of adequate capital are the major concerns related to sustainability. Capital and wealth can be used to address issues such as the substitutability and nonsubstitutability of renewable and nonrenewable forms of natural, human, and built capital.

Flow of products and services. Stewardship decisions revolving around the production of goods and services define the production within

Rationale for Economic Systems Modifications: Mt. Hood National Forest

The following principles for achieving sustainable development guided the development of the economic elements of the Mt. Hood LUCID analysis.

1. Maintain a sufficient capital base consisting of natural, built, human, and social/institutional/cultural resources, such that the system, e.g., the Mt. Hood Forest, will allow the sustained use of nondeclining levels of goods and services over the range of expected physical, economic, and social conditions into the foreseeable future. In short, the forest is managed in such a fashion that it will be resilient to external shocks in delivering its essential ecological, social, and economic services.
2. Distribute the goods and services in ways so that "equitable" access and benefit are achieved for all groups within society and between generations.

From these basic principles, it is clear that achieving a sustainable forest use pattern is inherently about providing all social groups of future generations with an adequate capital base to enjoy at least the same level of goods and services that current users enjoy. The determination of the capital base to pass on to future generations is a normative social decision about intergenerational welfare or equity. Uncertainty about environmental, social, and economic causes and effects requires a cautious approach to the selection of the stock levels for which we have little scientific knowledge, or run the risk of irreversibility. In such cases, society may choose to conserve minimum capital stocks to avoid irreversible future losses.

Economists are incapable of determining the "equitable" levels and composition of capital stocks to share among current users or to bequeath to future users. Ultimately, the choice of capital stocks is a social, and largely political, decision. Once the social choices about intergenerational capital stock levels are made, then economic theory and methods can be used to estimate the effects of alternative intergenerational allocation and to help find the lowest cost (i.e., most efficient) ways under uncertainty to achieve the social objectives. However, ecologists and social scientists must help inform society of the requirements and tradeoffs involved in achieving minimal capital stocks to assure ecological, social, and economic sustainability. This process inevitably must confront the appropriate standards with which to compare current indicators and verifiers.

The stocks are static measures and sustainable development is ultimately about finding a dynamic path of adjustment. Thus, measures of the annual flows of the goods and services are useful, as they foreshadow changes or trends in the critical capital stock levels. The annual flows may give early warnings of threats to the key stock levels, such as irreversibility thresholds. For example, the annual amount of recreation use may be above, below, or just equal to the flow that the forest can sustainably deliver without degrading the natural resource base delivering those services to future users. Thus, both stock and flow measures are necessary in the economic portion of the Mt. Hood National Forest sustainability assessment.

The economic analysis includes four criteria that capture the essential stock, flow, and equity principles.

1. Maintain minimum capital stocks, including natural, human, and built components. Note that the total capital stock necessary to pass on to future generations should include social, cultural, and institutional elements as well; but those elements are left to the social component of this study.
2. Deliver nondeclining flows of market services, such as timber, from the forest resource base.
3. Continue the supply of other key services that are not supplied or allocated through markets.
4. Seek benefit and cost distributional equity within the current generation.

(Source: Mt. Hood National Forest Team)

the regenerative capacity, or interest, of the natural system. The flow of goods and services can be used to address issues associated with the productive capacity of the landbase to provide a sustained flow of both market and nonmarket goods and services to society.

Function (Flow) Components

Equity. Equity is the fair distribution of the benefits and costs of national forests production and protection. Equity can be used to address issues such as distribution of income and employment and the equitable access to public facilities and services.

Kinds of Economic Systems	Economic Criterion			
	Structures (stocks)		*Function (flows)*	
	Capital and wealth	Flow of products and services	Trade and distributional equity	Efficiency
Individual Firm Industry Community				

Figure 18. The Final LUCID Core Economic System Framework

Efficiency. Efficiency is a condition in which benefits are maximized relative to costs. The stewardship of economic systems is maintained by the efficient utilization of resources in producing goods and services from the national forests. Efficiency is used to examine issues associated with the allocation and tradeoffs of the costs and benefits of stewardship and the efficiency in the consumption, production, and stewardship of the forest. Efficiency can be examined at a variety of different scales including a single firm or to society as a whole.

Although great progress has been made with the economic framework, what remains to be addressed is a more detailed examination on which stock and flow (structure/function) components should be examined within which kinds of systems (individual to community or regional economy) within the context of FMU-scale sustainability monitoring.

CHAPTER HIGHLIGHTS

- The structure and function of ecological, economic, and social systems are fundamental system properties, and by definition they are the criteria that describe the kinds of systems.
- Although we implicitly understand that ecological, social, and economic systems are strongly interconnected, there currently is no unified systems theory that provides a single model for ecological, social, and economic systems considerations.
- The explicit use of systems models was extremely useful as a tool to examine sustainability and as a way of framing the development of indicators and analysis approaches that were a significant improvement on our understanding of sustainability.
- A systems framework had several distinct purposes including: 1) Provide a means to communicate that sustainability is more than the sum of the individual elements (components/parameters) that are monitored; 2) Provide a strong theoretical, science-based link to understanding sustainability; and 3) Lead to a better description of elements for monitoring and a more meaningful method for synthesizing and analyzing results to understand the state of systems.
- The ecological framework is defined by the criteria of structure and function for each kind of ecological system including organisms, ecosystems, populations, and landscapes. The structure and function of these systems kinds are examined across a range of spatial scales.
- The social framework was structured by four criteria: 1) collaborative stewardship; 2) institutional and community capacity; 3) social equity; and 40 social and cultural values/opportunities examined across a range of kinds of systems including individuals and communities of place and of interest.
- The economic framework is defined by four criteria: 1) capital and wealth; 2) flows of products and services; 3) trade and distributional equity; and 4) efficiency that are examined across a range of economic system kinds from individuals to communities.
- Identifying those aspects of social and economic systems that are related to FMU-scale sustainability is challenging. Systems approaches to social aspects of sustainability within the context of forests are relatively new. Although significant progress was made that appears to have utility to national forests staff and collaborators, there is a need for continued research and development of social sustainability.

CHAPTER 8.
INDICATORS

BACKGROUND: WHAT IS AN INDICATOR? 115

- Examines different types and characteristics of indicators and their relationship to the LUCID indicators.

THE PROCESS OF DEVELOPING LOCAL-LEVEL INDICATORS 120

- Summarizes the development of the initial set of indicators and presents the methods used to revise indicators through the testing process.

THE LUCID EXPERIENCE: SELECTION, REVISION, AND ADAPTATION OF INDICATORS 122

- Reviews general changes to indicators wording, style, and organization and then highlights the results of indicator development within each of the principles.

IMPLICATIONS 132

- Discusses findings and implications regarding indicators of management process and enabling conditions, indicators of the interrelationships between systems, and the total number of overall indicators.

> "Indicators are designed to provide clear signals about something of interest. Indicators communicate information about the status of things, and, when recorded over time, can yield valuable information about changes or trends." *(National Research Council 2000).*

BACKGROUND: WHAT IS AN INDICATOR?

Indicators are simplifications of complex phenomena that indicate, or are a sign of, a specific condition of the phenomena. Typically, indicators are "small bits of information that reflect the status of larger systems" that are ways of "getting feedback about a system that might otherwise be too big and complex to understand" (Redefining Progress et al. n.d.). Indicators are used in a variety of ways in every day life from indicators of the state of the economy to indicators of our health. Any individual indicator, however, is merely a signal of the larger phenomenon or event we are interested in; and the information from an individual indicator must be integrated in an array of indicators to provide a more complete picture of a system.

Although the idea of indicators is used almost universally, the definition and use of indicators varies from application to application. Our focus was on the development and selection of indicators of sustainability.

What Makes a Good Indicator?

The challenge in indicator selection is to find an indicator that has all the characteristics of sustainability indicators as well as key characteristics common to good indicators regardless of type and purpose. Some of the many commonly cited characteristics of good indicators include:

- Relevant conceptual basis that shows something about the system and the stated goal/framework and is well understood and accepted in a conceptual model of the system
- Scientifically valid
- Scaled appropriately to the phenomena of study and the scale of decision-making
- Sensitive/Precise
- Robustness
- Responsive to change and providing an early warning of that change
- Relevant to needs of users
- Based on accurate, available, and accessible data comparable over time
- Understandable
- Comparable to reference values
- Comparable to indicators in other jurisdictions
- Cost-effective
- Unambiguous

Integrative Indicators

Sustainability indicators are "not just a collection of ecological, social, and economic indicators" but should also include "integrating indicators that illustrate the linkages among these three domains" (Maclaren et al. 1996). In this context sustainability indicators are selected to address the ways in which the ecological, social, and economic systems interact and have synthetic value. Integrative indicators may be individual indicators or they may be indexes or composites of several indicators.

Inter- and Intragenerational Equity Indicators

Sustainability indicators should capture aspects both of current conditions as well as considerations for future generations. In some cases separate indicators are needed while in other situations the reference values are developed based on a consideration of inter- and intragenerational equity. The specific focus on long-range, intrergenerational aspects, however, is one of the ways in which sustainability indicators tend to be fairly different. Although some indicators (e.g., income) in the LUCID Project focus on intergenerational issues, the fundamental approach of selecting indicators based on the systems, or context, that is sustained is in keeping with an intragenerational perspective.

Inclusive Development

Sustainability indicators also differ from other kinds of indicators in the ways in which they are developed. Since sustainability is a value-based concept, it makes sense that sustainability indicators are developed in a broad-based, inclusive way. Good sustainability indicators should be usable by people and should help local people address sustainability issues that aren't at the expense of global sustainability (Hart 1999).

Indicators or Indices

Composite indicators (indices) represent a specific grouping of two or more indicators (regardless of type) that are designed to integrate a great deal of information about a system parameter into a more usable form. Indices are useful in that they condense, integrate, and synthesize a variety of information to provide a single measure of a system; it is not surprising that their use is frequently promoted within the sustainability literature.

Indices are useful to quantify different sources of information in order to compare the state of a system in one location or at one period of time with another. Indices are typically built by creating a common scale for a variety of different indicators (e.g., Gross National Product). Because composite indicators combine a variety of information, they may be less useful in providing an understanding as to what specific parameters of the system are at fault and/or providing guidance for management intervention. "A composite measure of sustainability does not provide a well-balanced picture of a community's progress towards sustainability. An indicator that is used primarily to compare one community against another is not as useful as measures that show a community the direction in which to move. In order to become more sustainable, different communities have different needs and are starting at different points" (Hart 1999).

So while indices are inherently appealing because they can simplify information about complex systems, there is still need for a suite of indicators that can provide the information necessary to guide management. The best use of indices depends on selecting the appropriate scale of elemental information to be used in the indices.

Within the LUCID Project we encouraged the use of composites or indices at the measure level of the monitoring hierarchy to provide high quality information about a range of factors (e.g., watershed condition indices). Several teams tried to improve the level of information of indicators by focusing on the development of indices (e.g., watershed condition) to integrate across a broad range of items.

Indices
"Trying to run a complex society on a single indicator like the Gross National Product is literally like trying to fly a 747 with only one gauge on the instrument panel...imagine if your doctor, when giving you a checkup, did no more than check your blood pressure."
(Henderson 1991)

Outcome-Oriented Indicators

In addition to the intended use of the indicator (e.g., sustainability), there are various types of indicators that have application in different settings. Criteria and indicators monitoring initiatives and forest certification initiatives contain a broad mix of types of parameters (indicators and measures) including *inputs*, *management process, outcomes* or indicators of *enabling conditions* (Table 13). Some C&I and certification initiatives specialize in only one kind of indicator while others contain a mix.

Input indicators assess the quantity or quality of effort (e.g., money, energy) devoted to a situation. For example, "expenditures on riparian restoration" is an input indicator. Although input indicators can be useful as early warning signs for phenomena that are hard to detect within the short term and for tracking management actions, the reality is that a "high level of input does not always translate into a similarly high level of output" (Maclaren et al. 1996).

Within the LUCID Project the choice of a systems framework for sustainability monitoring was based on the premise of sustaining the social, economic and environmental contexts or systems that sustain us rather than on sustaining a specific suite of *inputs* (e.g., management actions) or *outputs* (e.g., quantity or quality of goods and services produced). This leads to the selection of

Table 13. Terms and Definitions Used to Categorize Indicators by Type

Indicator Type	**Definition**
Input	Actions or objects that are put in, or taken in, or operated on (e.g., dollars spent on restoration activities).
Outcome	The state or capacity of the ecosystem or related social and economic systems. Outcome parameters may be of either the structures or the functions of these systems (e.g., recreation visits or hydrologic function).
Management Process	A component of the management process, or other human action, describing human activities and not the result of the activity (e.g., seed transfer rules).
Enabling Condition	A broad kind of management process parameter used to create an environment that allows for sustainable management (e.g., periodic forest-related planning, assessment and policy review).
Source: Adapted from CIFOR 1996, Lammerts van Bueren and Blom 1997.	

outcome indicators that can be used to report on the status of the system. It is not essential that the cause(s) of the outcome (within a cause-effect relationship) be immediately known in order for outcome monitoring to be effective because additional studies/monitoring may be triggered by the results of monitoring efforts. This focus on the use of outcome indicators guided LUCID. The process involved starting with identifying fundamental system properties (Chapter 2) and then selecting a suite of appropriate indicators and later measures (Chapter 9) to assess the state of the system (including both structures and functions within the systems).

Forest teams were encouraged to develop outcome measures, although not exclusively. Input indicators were discussed as options when the inputs (e.g., volume of pollution spills) served as early warning signals of system change, particularly in cases where there might be a substantial lag time in the system response (i.e., outcome); when the responses were wide-spread, possibly affecting multiple parts of the system in potentially unknown ways; or when cause-effect relationships were fairly well known (e.g., fire risk index) and which management could respond to. Consideration was also given to selecting input indicators or measures as proxies when it was deemed to be currently too difficult to measure the outcome or state of the system for that particular parameter.

> *"Sustainable development seeks to meet the needs and aspirations of the present without compromising the ability to meet those of the future."*
> *(World Commission on Environment and Development 1987)*

Short- or Long-Term Outcomes: Sustainability for How Long

The word *sustainability* inherently conjures up the notion that it is a long-term proposition. In fact, specifying "for how long" is an important part of bounding interpretations of sustainability. Almost all definitions of sustainability contain reference to the importance of both intra- and intergenerational equity implying both a short-

Categorizing Outcome Indicators: Measuring Progress of Estuary Programs

The United States EPA Estuary Monitoring Program has developed a handbook to assist in measuring progress of estuary programs using a suite of outcome-oriented indicators. Using a "chain-of-events" scenario the EPA program outlines a progress of outcomes from intermediate outcomes through end outcomes. "Monitoring outcome indicators that measure first- and second-order outcomes has the advantage of enabling users to track estuary protection progress in a more timely fashion. First- and second-order outcomes generally occur relatively soon after program activities, while third- and fourth-order outcomes often occur later. Fourth-order outcomes—changes to living resources—sometimes may not occur until many years after corrective actions have been taken. The purpose of outcome monitoring information is to provide timely information…decisions often cannot wait; officials need information to make decisions even if the information available is far from ideal and represents only intermediate outcomes. Thus, first- and second-order outcomes provide early indications and can be considered proxy indicators of end outcomes."
(United States EPA 1994)

term focus (within generation) and a longer-term focus (multi-generational perspective). Consequently, even within an approach to sustainability that focuses on sustaining the context (a systems approach) there will probably be a mix of short- and long-term outcomes.

Other approaches to indicator development have focused specifically on long-term outcomes (National Research Council 2000) or have suggested that a specific effort be made to measure short-, mid- and long-term outcomes.

The Ottawa Forest Team proposed a set of further analyses of C&I specifically focusing on an examination of long-term outcomes. They proposed that the "sustainability analysis could be defined to have two reference points: existing system conditions or status, and short-term effects to those conditions, and, long-term or overall effects." Their long-term analysis "would examine if indicators suggest an improvement or decline in the fundamental ability of systems" to be sustained. The Ottawa Team anticipated that not only might it be possible that indicators (or measures) could be categorized as short-term, long-term, or both but that reference values could be expressed in two ways; a short-term outcome versus long-term outcome perspective.

The time frame of a sustainability assessment may be embedded in the concept inherent in the indicator or it may be associated with the reference value set for the indicator. For example, a common indicator in many C&I sustainability suites is employment (or income as a proxy). Employment (types, levels, and distribution) is best classified as a short-term outcome. An indicator focused on the development and retention of human capital (skill-base development and retention) could be classified as a mid-term outcome as it represents the investment in the next generation in achieving employment objectives. A related long-term outcome might be community resiliency focusing on the socioeconomic diversity and inherent resiliency within communities that may establish the context for future generations in employment or related outcomes.

In sustainability assessments there appears to be a significant difference in the distribution of short-term versus long-term outcomes between social, economic and ecological systems. The majority of ecological outcomes considered by LUCID and other C&I assessments focuses on long-term outcomes. Within LUCID's economic systems framework the maintenance of natural capital similarly has a focus on long-term outcomes. LUCID's social systems framework is focused both on short-term outcomes associated with the criteria of collaborative stewardship and mid- to long-term outcomes associated with the criteria of institutional and community capacity. The resulting differences in the distribution of the various time frames of indicators may be due in part to our inability to identify the fundamental structures and functions that are necessary to sustain the contexts of social and economic systems within the long-term. This may suggest an area for further research.

Sustainability and Resiliency

The concept of resiliency has often been linked in popular literature with the idea of sustainability. The inherent capability for sustainability can be defined as the "capacity to continue a desired condition or process" and resiliency as "the ability of a system to adjust its configuration and function under disturbance" (Allen et al. n.d.). A system that is resilient, then, is one that is able to recover from disturbances. Systems that have a limited amount of slack or resilience are not inherently unsustainable but they are fragile (Allen and Hoekstra 1992). Systems that persist for relatively long times generally have enough resilience to recover from large perturbations.

Many systems are inherently fragile: they may be characterized by less redundancy in trophic structure or they may be characterized by associations of species at the edge of their range. Fragile systems may have less slack or flexibility but they can be sustained.

Identifying the management priorities to ensure sustainability is key. Genetically improved seed, fertilizer, large-scale farm equipment, and irrigated cropland are examples of types of investments that push a system's equilibrium to a point away from the nominal position. Systems that are artificially pushed out of their nominal equilibrium will degrade below their original conditions when the inputs are reduced or withdrawn. So from the management application perspective, serious consideration needs to be given to moving systems existing points of equilibrium. One of the final questions asked of a monitoring system is what action or investment is needed to be made to sustain the ecological, social, and economic systems and for whom, for how long, and at what cost?

Explicit consideration of the temporal dimensions of sustainability (Chapter 3), whether they are expressed through the indicator or the reference values, is an important step in the development of a suite of indicators. The reality is that short and long term outcomes can conflict and discussion and reconciliation of these objectives will be necessary.

Some people involved in the LUCID Project suggested that only those indicators and measures that specifically focused on long-term outcomes should be considered sustainability indicators while the others were merely desirability indicators. Given that both intra- and intergenerational perspectives are normally considered in understanding sustainability (Chapter 2), limiting the suite of indicators (or reference values) to long-term outcomes would seem at least in this perspective to exclude one-half of the temporal dimensions of the sustainability discussions. While a specific analysis of long-term outcome indicators/reference values would be very valuable in understanding sustainability by itself, a long-term outcome focus may not be appealing to many collaborators.

Management Process and Enabling Condition Indicators

A number of C&I initiatives and many certification initiatives contain within them a strong focus on indicators or measures of management processes and/or enabling conditions. This approach is consistent with the sustainable forestry approach (Chapter 1) present in many forest certification systems. The management process approach tracks whether management actions are related to the achievement of sustainability.

Management Process Indicators

Management process indicators describe processes (e.g., seed source rules) or actions (e.g., stream restoration) taken and consequently are typically also input indicators. The assumption is that certain management processes or actions or conditions can lead to improved conditions of sustainability. Auditing (in the case of certification) or monitoring these parameters is often relatively straightforward and fairly simple to conduct. This approach, however, is not without its limitations. There are a number of critiques of some management process parameter suggests that they are only weakly linked to sustainability measures or in some cases that the parameters can conflict with achieving sustainability objectives. In some cases management process parameters represent the best available proxy measures to assess the state or condition of systems. As proxy measures, management process parameters may be used when methods have not yet been developed or methods are too expensive to monitor the condition of the parameter.

Within a larger context such as the pressure-state-response frameworks discussed previously (Chapter 2), tracking management actions or processes (the responses) and tying these indicators to the resulting state of the systems can be exceptionally beneficial. Additionally, management process parameters are typically much easier to assess or monitor; so they may represent a useful first approach to monitoring. Within the Forest Service implementation monitoring (the extent to which a set of programs or actions are carried out) and some forms of compliance monitoring are similar in approach.

In recommending a hierarchical framework for sustainability C&I, the Tropenbos Foundation suggested that management process indicators that were felt to be significant to just one criterion or indicator should be placed within that criterion or indicator (Figure 19).

Enabling Process Indicators

A subset of indicators that are much broader in scope than management process parameters is referred to as "enabling conditions" (e.g., the presence of a permanent forest estate will contribute to sustainability). These enabling conditions directly bear on more than one principle (ecological, social, and economic) and are not deduced from the principles; so Tropenbos suggested that they be organized in a separate hierarchy, parallel to but not embedded within the principles at the level of indicators.

Within the Montreal Process, criterion 7, the *Legal, Institutional and Economic Framework for Forest Conservation and Sustainable Management* describes a national-level framework that facilitates the conservation and sustainable management of forests and includes a broad range of enabling condition parameters including:

7.1c Extent to which the legal framework provides opportunities for public participation in public policy and decisionmaking related to forests and public access to information;

7.2b Capacity to undertake and implement periodic forest-related planning, assessment and policy review processes including cross-sectoral planning and coordination;

7.5b Development of methodologies to measure and integrate environmental and social costs and benefits into markets and public policies.

Because the Montreal Process C&I are intended to provide an international reference for policymakers in forming national policies and act as a basis for international cooperation, it is not surprising that within criterion 7 a larger number of indicators have been selected to provide a legal, institutional, and economic framework for forest conservation and sustainable management. The indicators in this criterion address conditions and processes of larger society and although external to any given forest may at a forest level, "affect efforts to conserve, maintain, or enhance one or more of the conditions, attributes, functions, and benefits" (Oregon Progress Board 2001).

Although the typology is somewhat different than that suggested by the Tropenbos Foundation, the Montreal Process achieved this type of separation or distinction by placing these parameters under one criterion (*principle* in the Tropenbos and LUCID terminology).

THE PROCESS OF DEVELOPING LOCAL-LEVEL INDICATORS

The Role of Indicators in the LUCID Project

Within the context of the LUCID Project, an indicator is a parameter that can be assessed in relation to a criterion. To be broadly applicable across a range of forests and settings, indicators are defined in ways that do not imply a direction, measurement method, or reference value. Because measurement methods are not implied, indicators can be assessed either quantitatively or qualitatively. Within the LUCID monitoring hierarchy the indicator level provides a generic set of assessment parameters that are broadly applicable to all national forests settings. LUCID indicators are measurement parameters of the sustainability and specifically of the state of the interacting ecological, social, and economic systems that sustain us. By themselves individual indicators are neither sustainable nor unsustainable. Rather the suite of indicators when considered together helps us to achieve, albeit in simplified form, an understanding of the sustainability of systems.

The intent within the LUCID Project was to determine whether a suite of indicators could be developed for assessing the sustainability of national forests within their regional contexts. The intent of indicator development was to identify necessary and meaningful indicators that examined the state (based on an outcomes orientation) of the systems that sustain us. The task was to determine, through a testing process across a range of national forests conditions, whether there was a core set of indicators that could be used more broadly by national forests to monitor system sustainability.

In addition to the development of a suite of measurable parameters, the process of developing, testing, and measuring indicators helps develop a language of sustainability and gives location-specific meaning to the sustainability of systems. Indicators provide a means of engaging communities and collaborators in talking about what is important to them.

Development of Indicators—Origin of the Core Set

The development or choice of indicators can often be challenging. There is a growing body of literature on the process and methods for developing criteria and indicators for monitoring (see for example Lautenschlager 1988 and CIFOR 1996). Generally, however, there are two broad approaches: 1) start with existing sets of indicators and screen these lists (screening approaches), or 2) start with principles, issues of concern or stresses and develop indicators for each of these (clean-slate approaches). Each approach has its advantages and disadvantages. Indicators are not generic, however; and while valuable sources for developing indicators exist, they must be adapted and tested in the local context.

For the purposes of the LUCID Project, we chose to combine both approaches. Our first task was to develop a model, or framework, of the systems (ecological, social, and economic) we wanted to monitor. Based on the development of these systems frameworks, available indicators were reviewed and filtered to generate a LUCID core set of indicators to serve as the starting point, or "straw-dog"' set of indicators.

The primary suite of indicators reviewed through the systems framework was the set resulting from the CIFOR-NA test. This set was in itself the result of a successive filtering process. The original indicators reviewed during the CIFOR-NA set were the Canadian Council of Forest Ministers C&I (a set similar to the Montreal Process), the Fundy Model Forest indicators, the State of Idaho Forest Practices Code set, the CIFOR social and economic indicators, and the CIFOR master sets which themselves were the result of testing various sets of indicators.

The LUCID core team then reworked the resulting CIFOR-NA indicators by developing the frameworks discussed above and reviewing the possible indicators through a lens of these system frameworks. Most indicators from the CIFOR-NA set fit somewhere into the frameworks, but some were found to be redundant or less applicable to the LUCID Project. In other cases CIFOR-NA indicators were split apart or reorganized. In a few other cases the LUCID core team developed new indicators to fill gaps. During this review process, the LUCID core team also revisited various original sets of indicators (e.g., Montreal Process, Forest Stewardship Council, CIFOR) to determine if any provided a better fit for the initial set of indicators. Indicators, regardless of source, were often modified in an attempt to remove standards (reference values) and measurement implications or other definitional challenges. However, forest teams quickly determined that not all necessary definition changes had been made.

The Method of Adaptation

Each forest team received the same set of initial LUICD indicators. Although the initial set provided a common starting point, forest teams were encouraged to examine indicators from the other forest teams as well as from other available sets of indicators, particularly local or regional indicators that may be available. The primary options for adaptation of these local-level indicators (Figure 19) were to review the initial indicators and:

1. Accept indicators without modifications;
2. Accept indicators with modifications;
3. Reject indicators;
4. Propose new indicators;
5. Reorganize indicators within the existing or a revised systems framework.

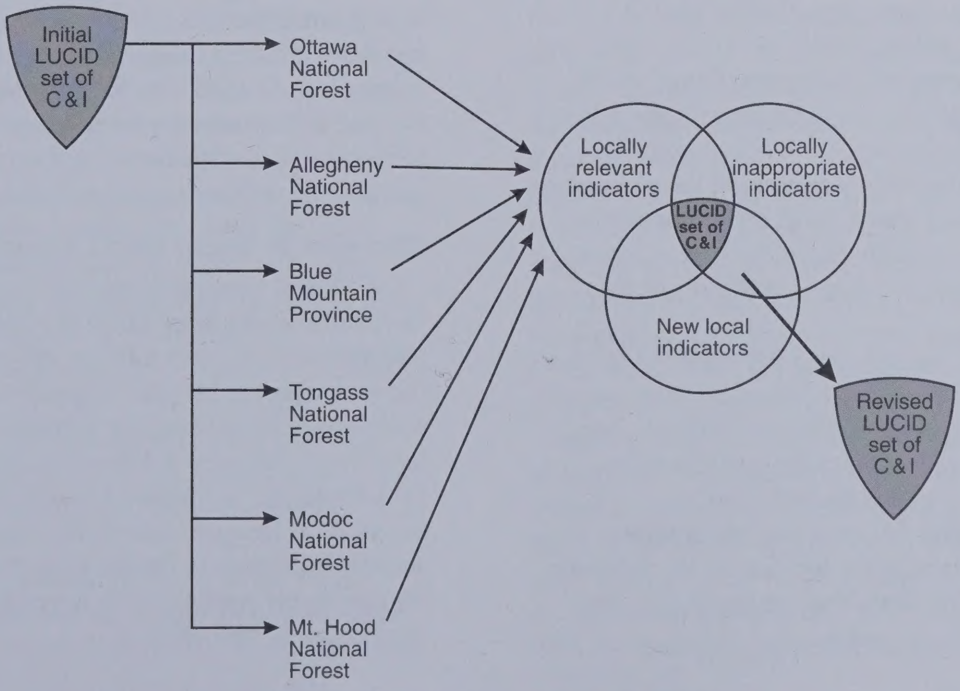


Figure 19. Indicator Evaluation Options

THE LUCID EXPERIENCE: SELECTION, REVISION, AND ADAPTATION OF INDICATORS

While the LUCID forest teams began their review of indicators at the beginning of the test process, it was found that the selection, review, and adaptation of indicators was iterative and that it continued to the end of the project. Forest teams noted that it was important to continually reaffirm how each indicator contributes to an assessment of its associated criterion. Although many forest teams noted that given the limited time for review and typical working styles they tended to refine indicators on a disciplinary basis (e.g., economist worked alone or with other economists), they also noted that the indicator selection and review process was most innovative and productive when the team worked in an interdisciplinary setting.

In the process of identifying key indicators, most forest teams felt that it was very important to not limit the set of C&I to parameters that could be assessed only within areas of Forest Service ownership; but rather good indicators would work across all types of land ownership. Forest teams were also challenged to develop the ideal set of indicators without being restricted to what was currently being monitored. Working within a systems context, forest teams reviewed the core set of C&I as well as indicators from other programs (e.g., Sierra Nevada Province, Bi-National Committee, Great Lakes) to adapt a set of locally appropriate indicators. Forest teams worked through several iterations of their selected indicators to refine the list to those judged essential and feasible. However, at the completion of the project all teams noted that more work is still needed to identify key indicators and pare down the list of associated measures and data elements.

Although the individual approaches varied from forest to forest the types of changes made by the forest teams were relatively common. The original core set of indicators went through a variety of revisions including: wording clarification changes, lumping and splitting changes, changes of the location of the indicator within the framework, and changes associated with scale and ownership.

Wording Changes

Indicators were reworded for clarity, to remove measurement, direction, and reference values, to correspond to Forest Service use, and to make them applicable across a range of forest/nonforest conditions.

Lumping and Splitting Changes

These changes were often needed to ensure that the meaning of an indicator was clear to the users. Lumping or splitting was undertaken to create a balance between providing sufficient detail so that the meaning is clear but not so much detail that the meaning is lost. The choice of whether to lump or split indicators had a lot to do with the actual meaning or intent implied by the indicator, particularly in relation to its associated criterion and to sustainability. For example, splitting might include an indicator of fire cycles, whereas lumping would include a more broadly worded indicator of disturbance processes. Considering the associated criterion is Landscape Function, the more broadly worded indicator is more clear in that it focuses less on the specific disturbance and more on the ecological function of the phenomenon from a sustainability perspective.

Location within Monitoring Framework Changes

For the social and economic principles where there were substantial changes to the systems framework and associated criteria, changes to the location of indicators within the hierarchy were inevitable. In the ecological principle, where the framework changed very little, revisions to the location of the indicator were associated with more critical examination of the systems concept and how the indicator related to the criterion.

Changes in Scale and Ownership

As forest teams explored the issues of scale wording, changes were made to address the inherent scale necessary for an indicator to assess the component or process in question. Changes were also made in indicator wording to make them applicable across a broad geographic range of forested and nonforested conditions and ownerships. In some cases it was necessary to add specific indicators to the list (e.g., some indicators for non-forest conditions) to cover all possible conditions for an indicator.

In addition to revising the core set of C&I, forest teams added indicators in many areas, particularly within the social principle. Relatively few indicators were deleted outright. An indicator-by-indicator review of the changes of the initial set to each of the six forest teams would be too extensive, so the next sections highlight some of the key revisions, additions, or deletions made by the forest teams.

It is difficult to convey the full meaning of the indicator (and similarly with principles, criteria and measures) through a simple name. The intent of the indicator is described more fully by understanding its place in the systems framework (e.g., what criterion is it organized within), a description and definitions of terms, and a discussion of the relationship of the indicator to sustainability.

The LUCID Resource Database (Appendix 9 CD) contains the complete documentation of this information on each of the selected indicators. Additional background information on the LUCID Resource Database is described in Chapter 11.

Social Indicators

Compared to ecological systems, the development of indicators of social sustainability within the context of the FMU scale is in its infancy. Many C&I have not traditionally included social indicators or have included them only at a broad policy or enabling condition level. The social principle, more so than any other principle, went through a series of framework changes (Chapter 7) that led not only to changes in the location of indicators within the framework but also the addition of several new indicators (Table 14).

The majority of the initial set of indicators was reconfigured within one criterion (1.4) and expanded or new indicators were developed in the areas of collaborative stewardship (1.1), institutional and community capacity (1.2), and social equity (1.3) (Table 15). Given the artificiality in the separation of the social and economic principles, some indicators also shifted between principles (initial indicator numbers 3.2.5 and 3.3.3).

Through the tests, the focus of the social indicators broadened to include aspects of social well-being. Although this has broadened the scope of the social indicators beyond policy and strategic enabling conditions, the selected indicators do not encompass the full range of social well-being that might be appropriately included in community sustainability initiatives. Instead, the focus is more closely on forest-related aspects.

Table 14. A Summary Comparison of the Initial and Final LUCID Social Criteria

INITIAL CRITERION - SOCIAL	FINAL CRITERION - SOCIAL
C1.5 Involvement values	C1.1 Collaborative stewardship
X	C1.2 Institutional and Community Capacity
C1.6 Forest-based human health values	C1.3 Social equity
C1.1 Spiritual and cultural values	C1.4 Social and cultural values
C1.2 Aesthetic values	
C1.3 Recreational values	
C1.4 Access	
C1.7 Gathering (non-economic) forest values	

LUCID participants found these indicators to be useful in helping understand the state of social systems within and affecting the FMU; however, there remains a significant need for further research on social indicators and measure (protocol) development. A number of the social indicators (and similarly some economic indicators) do not yet have the desired information value. Although the indicators are worded such that they imply neither quantitative nor qualitative measures in an attempt to identify the common threads of social well-being that can be assessed consistently from forest to forest, we feel there may be a movement to focus almost exclusively on quantitative approaches (e.g., number of collaborative initiatives, number of stewardship contracts). Indeed, the initial set of measures (Chapter 9) developed for these indicators are consistent with this kind of approach. The number of activities (e.g., participation opportunities) or features (e.g., cultural sites) only tells part of the story. A full assessment of social well-being relies upon an assessment of the quality or perception of the adequacy, fairness, or effectiveness of features, facilities, processes, and institutional arrangements.

Table 15. Comparison of Final to Initial Social Indicators

Principle P1. Social values related to the forest are maintained		
FINAL CRITERION	**FINAL INDICATOR**	**INITIAL INDICATOR**
C1.1 Collaborative stewardship		
	I1.1.1 Contribution of local and traditional and ecological knowledge	X
	I1.1.2 Collaborative decision-making	1.5.1 Participation/involvement in decision-making
	I1.1.3 Stewardship activities	X
	I1.1.4 Local area empowerment and development	X
C1.2 Institutional and Community Capacity		
	I1.2.1 Community resiliency	3.2.5 Resource production component
		3.3.3 Community economic diversity
	I1.2.2 Institutional adequacy	X
	I1.2.3 Ownership patterns	1.4.2 Ownership and use rights
	I1.2.4 Government-to-government relationships	X
C1.3 Social equity		
	I1.3.1 Environmental justice and civil rights	X
	I1.3.2 Disabled access	X
	I1.3.3 Worker health and safety	1.6.1 Worker health and safety
	I1.3.4 Public health and safety	1.6.2 Public health and safety
	I1.3.5 Community/environmental health	X
C1.4 Social and cultural values		
	I1.4.1 Gathering	1.7.1 Subsistence and nonsubsistence gathering
	I1.4.2 Aesthetics and solitude	1.2.1 Scenery
	I1.4.3 Education and research	1.3.1 Recreational, tourism, and education opportunities (by activity)
	I1.4.4 Cultural values and historic features	X
	I1.4.5 Spiritual values and special places	1.1.1 Wilderness
		1.1.2 Aboriginal and nonaboriginal cultural, spiritual, social sites/values
	I1.4.6 Access and use rights	1.4.1 Access to forest resources
	I1.4.7 Recreation and tourism	1.3.1 Recreational, tourism, and education opportunities (by activity)
	I1.4.8 Customs and culture	X

In other areas some promising work has been started to combine basic demographic data into more meaningful indices (see, for example, the community capacity indicator). Although different approaches to such indices have been pioneered in a number of different applications in Forest Service and other contexts (e.g., ICBEMP), additional research is needed to identify the most discriminating and rigorous ways of understanding social well-being.

LUCID forest teams engaged in a number of discussions about the relationships between social indicators and sustainability. More so, or at least more obviously so, than in the other principles there was a recognition that causal relationships between social indicators were not straightforward.

More, of the feature or activity or process, is not necessarily better. For example, more public participation opportunities does not necessarily indicate a better situation—in fact, high numbers of public meetings with no real opportunity for meaningful involvement may lead to an exhausted, disillusioned, and mistrustful public. The converse is also true—less of something may not be desirable either. Concentration (as opposed to diversification) of ownership in the hands of a few does not necessarily cause unsustainable practices; but there is a growing body of research to suggest that ownership concentration, particularly in industrial or nonlocal owners without significant compensating opportunities, is more likely to lead to inequities and ultimately a decline in the feeling of responsibility, stewardship, and sense of place within an area. And in both the case of public participation and ownership patterns, the role and meaning will change from place to place.

Predicting the exact nature of the relationship of the indicator to sustainability for parameters such as those related to public involvement, ownership patterns, and others within the social principle is next to impossible. However, the literature and applied tests in other locations support the inclusion of these indicators as potentially critical factors in assessing sustainability. What emerged clearly from the LUCID Project, however, was the critical need for forest teams and collaborators to work together to probe how the indicator is related to sustainability in their given situation and what specific aspects of the indicator are relevant in their area (e.g., parcelization or type of owner for ownership patterns).

Collaborative Stewardship Indicators

The involvement of the public in decision-making is one area that is frequently included in sets of C&I, particularly for forests within the public trust. Given the emerging understanding and importance of the role of values in sustainability and collaborative approaches to management, additional indicators were added to focus on collaborative stewardship issues and approaches in ways that go beyond traditional public involvement. Measuring these indicators to produce high quality information and setting reference values are still very difficult as it is typically the nature of the involvement and not the quantity of the involvement that is most important.

Local area empowerment and development were combined as one indicator added to focus on long-term outcomes and intragenerational equity aspects both of collaboration (communities that are empowered and have sufficient skills are more skilled in interacting) and in the development of the future labor pool.

Institutional and Community Capacity Indicators

Several forest teams highlighted the importance of issues associated with community capacity or community health. The Tongass Team, for example, indicated that they felt community health measures "were necessary within the context of issue identification and monitoring, particularly in relation to acute local economic distress." The associated measures were initially located between community capacity in the social principle and the distributional equity indicators in the economic principle and to some extent this is still the case. A community resiliency index (see for example Kusel 1996 and Harris et al. 1998) that combined information from several important indicators was seen as the best way of converting traditional demographic descriptive data into meaningful indices.

Most forest teams found that assessments of the status of enabling condition indicators best fit within this criterion largely under the institutional adequacy indicator. The extent to which forest teams felt there should be a focus on enabling conditions varied substantially with some teams advocating the inclusion of a larger suite of associated indicators and measures.

Forest teams were asked to explicitly consider the application of C&I to the Tribes who accessed or whose traditional territory encompassed the national forests. In other jurisdictions (e.g., Canadian Council of Forest Ministers suite of C&I, Canadian Model Forest Program) specific sets of C&I and associated measures have been developed to address the sustainability perspectives of aboriginal peoples. A few of the LUCID forests were able, even during the restricted time frame of the LUCID Project (e.g., Tongass and Ottawa National Forests), to begin to meet with the appropriate resource people to identify some good preliminary indicators and measures to capture American Indian perspectives. Forest teams noted, however, that monitoring indicators associated with treaty rights and tribal interests require input from American Indians and "any meaningful indicators would need to be developed with the tribes of interest in the area" (Blue Mountain Forest Team).

Social Equity Indicators

More traditional indicators of public and worker health and safety were expanded to include indicators to assess equity issues of traditionally disadvantaged populations (e.g., environmental justice and disabled access indicators). The community/environmental health indicator is a synthetic or integrative indicator that makes a direct linkage between the environmental services that the ecological system provides and social sustainability.

Customs and Culture

The social value of the sense of place that national forests have was recognized as a critical component that shapes the uses, customs, and cultures of residents and visitors. Forest teams like the Modoc highlighted the value of including such measures but noted that this indicator "presented the most difficulty in the social set because of the diverse and independent nature of local culture." Given the high degree of variability and challenges with measurement, this indicator was approached in a number of different ways by forest teams and is an area where great flexibility in definition and measurement approaches will be needed. Some forest teams approached the indicator in more numeric ways, assessing the number of facilities, services, or mechanisms (e.g., a Forest Sense-of-Place document) for recognizing the value of the place. Some approached the indicator in terms of an overall social survey on satisfaction with management for the values that the forest held, and others felt a more detailed social assessment that was built on community-defined communities of interest (see, for example, Doak and Kusel 1997) was an approach to measurement.

Ecological Indicators

Relatively speaking, much more attention and effort has been devoted historically to the selection of ecological indicators both in other sets of C&I and specifically within the Forest Service. Framing the indicators within a systems approach (i.e., landscape, organism) considered in terms of the structure and function components of these systems was fundamental to LUCID and is the primary difference from other approaches that have developed C&I to monitor sustainability. Although the ecological criterion changed little from the initial to the final suite of C&I (Table 16), explicit use of the systems framework meant that there were a number of changes from traditional ecological indicators to monitor sustainability.

Most ecological monitoring efforts have focused on population systems though increasing attention is being paid to landscape systems. This parallels the advances in remote-sensing technologies and geographic information systems and increased recognition of the importance of landscape structures and functions as expressed in the conservation biology literature. In comparison with other sets of C&I to assess sustainability, there is much greater emphasis in the LUCID set of C&I on indicators of ecological function and indicators that assess a range of different kinds of systems.

Although the meaning and associated measurement methods of the core set of C&I evolved significantly during the LUCID Test, there were relatively few changes to the basic concepts included within the initial set of indicators (Table 17). A number of revisions occurred that are best categorized as lumping/splitting changes (e.g., a series of air, water, and soil quality indicators were lumped under one indicator I2.4.1). Indicators associated with the criteria ecosystem function and organism function and structure did evolve significantly during the test.

Table 16. A Summary Comparison of the Initial and Final LUCID Ecological Criteria

INITIAL CRITERION - ECOLOGICAL	**FINAL CRITERION - ECOLOGICAL**
C.2.1 Landscape function	C2.1 Landscape function
C.2.2 Landscape structure	C2.2 Landscape structure/composition
C.2.3 Ecosystem function	C2.3 Ecosystem function
C.2.4 Ecosystem structure	C2.4 Ecosystem structure/composition
C.2.5 Population function	C2.5 Population function
C.2.6 Population structure	C2.6 Population structure/composition
C.2.7 Genetic function	C2.7 Organism function
C.2.8 Genetic structure	C2.8 Organism structure/composition

Long-term Community Dynamics

The Mt. Hood Forest Team suggested adding the indicator termed "long-term plant community dynamics." The focus on long-term community dynamics assesses changes in dominant species based on vegetation history derived from pollen cores, presence of historic soil profiles, and fossil evidence of past plant/animal communities. Although it may be impractical to completely recreate the forest landscape of the past because of changes due to agriculture, forestry and urbanization, it is valuable for resource managers to determine a historical benchmark for comparing human impacts (Forbes et al. 1998). The measurement potential for this indicator is still under development, but the Mt. Hood Team highlighted the importance of this concept as a key indicator of landscape function.

Ecosystem Function Indicators

Consideration of ecosystem function includes issues of productivity and carbon among others. As has been found in other locations (e.g., Canadian Model Forest Local Level Indicator Program, CIFOR-NA), issues of carbon and global climate change are difficult to assess at the FMU scale. While intensive site-based data are needed to inform analysis, much analysis occurs at spatial scales that include geographic areas far larger than the FMU. Consequently, many LUCID forest teams found it difficult for an individual forest to monitor issues associated with climate change or carbon sequestration, feeling that "they would be better assessed at a larger geographic scale" (Mt. Hood Forest Team). However, given the importance of forest management's contribution to carbon and climate change, it was felt that forests do need to make a contribution to these efforts. Several recent studies (see, for example, Canadian Forest Service 2000) have focused on carbon budget accounting at the FMU scale and associated monitoring protocols. Indicators of carbon sequestration and related indicators of nutrient cycling, productive capacity, and ecological legacies are included in the suite of indicators although practical and feasible measurement methods for carbon sequestration and productive capacity are still needed.

Productivity measures, while strongly linked to considerations of carbon and climate change, are critical to sustainability issues yet contain their own measurement challenges. Monitoring of both primary and net productivity has typically focused only on commercially valuable tree species and is based on intensively sampled plot-based data. From an ecosystem sustainability perspective a much broader approach and analysis is needed and remotely sensed technologies hold some promise in this area. The development of practical measures for assessing productivity is an area of research and development that select LUCID forests are pursuing with the Forest Services' Remote Sensing Application Center (RSAC).

Organism Function and Structure Indicators

Organism systems are defined by the individual organism's structure and function and include such things as cell types and processes including respiration, reproduction, and growth. Although Forest Service involvement in monitoring of organism systems is relatively limited, there are some areas that are focal points for sustainability monitoring. Within the indicator "air, soil and water quality," the pollution effects on vegetation such as assessed through FIA/FHM ozone damage assessments is one possible measure that is interrelated with organism functions. For the most part, however, the LUCID Project focused on organism systems structures associated with genetic diversity and functions, including mixing, migration, and selection that affect genetic diversity. Although most sets of C&I acknowledge genetic diversity issues as important to sustainability, the development of a limited set of key outcome-oriented measures to monitor organism systems is limited.

Building on the work of CIFOR (see Namkoong et al. in prep.) and the CIFOR-NA test specifically, a suite of genetic indicators and suggested measures were tested during the LUCID Project. These indicators focused on priority areas where forest management was most likely to have a significant effect. Given the expense and difficulty in widespread application of genetic measures, it is suggested that the bulk of the genetics indicators be assessed from a management process/input perspective. One area that has not yet been sufficiently addressed is the issue of genetic enhancement (e.g., genetically modified organisms). This issue and related topics will probably come more to the forefront as plantation forests embark on this type of process.

Table 17. Comparison of Final to Initial Ecological Indicators

Principle P2. Maintain Ecological Integrity		
FINAL CRITERION	**FINAL INDICATOR**	**INITIAL INDICATOR**
C2.1 Landscape function		
	I2.1.1 Disturbance processes	I.2.1.2 Disturbance processes
	I2.1.2 Hydrologic function	I.2.1.1 Hydrologic condition
	I2.1.3 Long-term community dynamics	X
C2.2 Landscape structure/composition		
	I2.2.1 Landscape diversity	I.2.2.1 Vegetation types and structural classes
	I2.2.2. Landscape patterns	I.2.2.2 Fragmentation and connectivity
C2.3 Ecosystem function		
	I2.3.1 Productive capacity	I2.3.2 Primary productivity
	I2.3.2 Functional diversity	I.2.6.2 Community guild structure
	I2.3.3 Invasive species	I.2.6.1 Exotic species
	I2.3.4 Nutrient cycling	I.2.3.1 Nutrient cycling
	I2.3.5 Carbon sequestration	X
	I2.3.6 Stream function	I.2.4.6 Morphology and function of stream channels
C2.4 Ecosystem structure/composition		
	I2.4.1 Air, soil, and water quality	I.2.2.5 Water quality (e.g., dissolved oxygen, suspended sediments, and water nutrients)
		I.2.4.1 Pollutants
		I.2.4.2 Soil quality (e.g., soil compaction, displacement, erosion, puddling, loss of organic material)
		I.2.4.3 Soil nutrients
	I2.4.2 Ecological legacies	I.2.4.4 Ecological legacies and structural elements
	I2.4.3 Special habitats	I.2.4.5 Ecologically sensitive areas (e.g., riparian areas are retained)
	I2.4.4 Species richness	I.2.6.3 Species at risk
C2.5 Population function		
	I2.5.1 Population viability	I.2.7.2 Minimum viable populations
C2.6 Population structure/composition		
	I2.6.1 Populations of indigenous species	I.2.5.1 Populations of indigenous species
C2.7 Organism function		
	I2.7.1 Genetic mixing	I.2.8.1 Nonnative or enhanced stock
	I2.7.2 Genetic migration	X
	I2.7.3 Genetic selection	I.2.8.1 Nonnative or enhanced stock
C2.8 Organism structure/composition		
	I2.8.1 Genetic diversity	X

Overview of Genetic Process Issues of Concern on Mt. Hood National Forest

- **Artificial selection** refers to any activity which selectively removes individuals from populations affects genetic variation. Timber harvesting, precommercial thinning, Christmas tree harvesting, transplant contracts, and pole-cutting are examples of treatments that exert artificial selection. Additionally, tree improvement programs, seed-collection procedures, nursery treatments, and planting operations exert selection pressures on populations of plants planted in forest environments. (Zobel and Talbert 1984, Theisen 1980).
- **Migration** refers to the movement of individuals among populations, or subpopulations. Introducing individuals through planting can have favorable effects, such as introducing alleles for disease resistance or rapid growth. Conversely, unfavorable effects can result from the introduction of maladapted individuals (off-site planting stock) which may not survive and grow for the expected time period and may contaminate local gene pools with pollen and/or seed (Theisen 1980, Ledig 1992). Another concern is changing population structures joining previously subdivided populations into one population through planting or removing barriers to migration.
- **Genetic drift** refers to fluctuations in and loss of genetic variation in small populations (Hartl 1988). Genetic erosion due to chance extinction of fragmented populations may occur (Ledig 1992) and may have serious consequences in populations at the edge of a species' range. (Incense cedar and sugar pine are two species for which the edge of the natural range occurs on Mt. Hood N.F.) Effective population sizes of several hundreds of individuals equally contributing to reproduction are considered adequate to maintain genetic variation in populations over many generations (Lande and Barrowclaugh 1987). Census populations need to be larger, one to two thousand individuals or more, to ensure having an effective population size of 500.

(Source: Adapted from Mt. Hood Forest Team)

Some of the LUCID forest teams felt that focusing on genetics was currently beyond their ability; however, a few of the teams were able to forge connections with genetic specialists and suggest some improvements to the proposed genetics indicators. In conjunction with the regional geneticist, the Mt. Hood Team did a fairly thorough review of the genetics indicators. Ultimately, the team chose to focus specifically on genetic function (i.e., processes that shape populations and genetic variation). This team concentrated on how genetic variation is organized, maintained, eliminated, or dispersed according to the selection, migration, and genetic drift processes.

Economic Indicators

Although several forest teams found it valuable to deconstruct the economic criterion in the process of testing, the final economic framework is relatively similar to the original. One new criterion, and consequently new indicators, was added; but at the framework level the other criteria were stable apart from some modifications to their names (Table 18).

Within the criteria, however, discussions and justifications of systems structures and functions led to the addition of new indicators and to the movement of several indicators from criterion to criterion. New or substantially revised indicators were added within the capital and wealth criterion (e.g., built and human capital indicators) (Table 19).

Table 18. A Summary Comparison of the Initial and Final LUCID Economic Criteria

INITIAL CRITERION - ECONOMIC	FINAL CRITERION – ECONOMIC
C3.1 Wealth and capital accumulation	C3.1 Capital and wealth
C3.2 Production and consumption considerations	C3.2 Flows of products and services
C3.3 Trade and distribution considerations	C3.3 Trade and distributional equity
X	C3.4 Efficiency

Table 19. Comparison of Final to Initial Economic Indicators

Principle P3. Yield and production of goods and services		
FINAL CRITERION	**FINAL INDICATOR**	**INITIAL INDICATOR**
C3.1 Capital and wealth		
	I3.1.1 Natural capital - forests	3.1.2 Land base available for production
		1.1.1 Wilderness
	I3.1.2 Natural capital - recreation	3.1.2 Land base available for production
	I3.1.3 Natural capital - wildlife/fish	3.1.2 Land base available for production
	I3.1.4 Natural capital - range	3.1.2 Land base available for production
	I3.1.5 Other natural capital	3.1.2 Land base available for production
	I3.1.6 Built infrastructure - roads and trails	X
	I3.1.7 Built infrastructure - recreation facilities	X
	I3.1.8 Built infrastructure - other facilities	X
	I3.1.9 Human capital	X
C3.2 Flows of products and services		
	I3.2.1 Production of marketed goods and services	3.2.1 Annual and periodic removals of products (timber and non-timber)
	I3.2.2 Production of non-marketed goods and services	3.2.1 Annual and periodic removals of products (timber and non-timber)
		3.2.3 Money spent by visitors in local communities (by activity)
C3.3 Trade and distributional equity		
	I3.3.1 Trade balance	3.1.1 Community economic trade balance (imports and exports)
		3.2.4 Value to products including value-added through downstream processing
	I3.3.2 Workforce diversity	X
	I3.3.3 Income	3.2.6 Income from National Forest activities
		3.2.3 Money spent by visitors in local communities (by activity)
		3.2.7 Employment of local population in resource management
	I3.3.4 Equity	3.3.2 Mechanisms economic benefits sharing
C3.4 Efficiency		
	I3.4.1 Net rent	X

Capital and Wealth Indicators

The original core set of indicators focused on an assessment of the volume of natural capital. Two significant changes were made to the capital indicators that substantially broadened their original focus. Almost all of the forest teams expanded the indicator(s) beyond an assessment of natural capital to include human (labor) and built capital. The Mt. Hood Team promoted the movement to assess not just the volume of these capital resources but also their respective value. With the assistance of economists from Portland State University, the Mt. Hood Team piloted an attempt to quantify the value of capital stocks and is continuing to pursue alternative measures to refine this approach.

Trade Balance

The indicator "trade balance" went through extensive and divergent discussion within many of the forest teams. Although some did not feel that community economic trade balance (e.g., imports: exports) was particularly relevant to sustainability, others felt that it was very important to include.

Income and Employment Indicators

Indicators of income and employment are included in almost every set of sustainability C&I as they represent both easily measurable and easily understandable issues. In many C&I sets income and employment are viewed as one of the many goods and services that are produced or as merely a factor (an input) in the production of goods and services. The amount of local income or employment (vs. gross) is typically the issue, and it is often a proxy for distributional equity (Woodley et al. 2000). The forest teams each had different rationale for the focus on income/ employment issues; but the final rationale was the perspective that income and employment, while a product (or byproduct) of production, are key mechanisms from a distributional perspective.

In the final set of recommended indicators, income is highlighted as the preferred indicator although many forests may choose to include employment optionally as well. Our selection of only one indicator, income, was an attempt to focus and limit the number of key indicators to be included although there is some overlap from an employment perspective with the workforce diversity indicator. As income and employment are highly auto-correlated and an assessment of income can provide additional information, we felt this indicator should be the priority. As Hart (1999) notes, looking at average income or similar measures can conceal many important aspects related to sustainability. Consequently, the measures have a key focus on distributional aspects in terms of who and how many people get what.

Distributional Equity

Issues of distributional equity, both inter- and intragenerational were foremost for many teams. Forest teams suggested that the original approach to examining issues of distributional equity that focused specifically on mechanisms such as the distribution of the Payments-in-Lieu-of-Taxes (PILT) and the 25 percent fund were too narrow and other mechanisms that were used to distribute benefits and costs should be included. As Ruitenbeek and Cartier (1998) noted, the development of negative (the absence of equity) measures to assess these types of issues is much easier than assessing the extent of equity. This is one area, although critically important, that needs additional research to identify the best indicators and measures.

Net Rent

The efficiency of forest management, the production of goods and services, or the stewardship of the forest is a key, but often under-emphasized, component of the question: sustainability at what cost? Several forest teams promoted the inclusion of indicators to assess these efficiency aspects. The economic concept of rent focuses on assessing whether or not there is a fair return (income) for expenditures in a number of different categories from production components to stewardship components. This indicator was considered very important by many forest teams as it addresses the question of sustainability at what cost.

The Efficiency Indicator: An Allegheny Perspective

Efficiency attempts to measure the cost-effectiveness of Allegheny National Forest activities, the relative size of revenues and costs, and the generation of externalities. Clearly, cost-effectiveness is a key component of efficiency. Government programs are often criticized for not being cost effective, and the USDA Forest Service has not been immune from such criticisms..... Being below cost would not necessarily be bad. However, it would be good to monitor just how "below cost" various programs are.

(Allegheny Forest Team)

IMPLICATIONS

Management Process and Enabling Condition Indicators

The suite of C&I from the CIFOR-NA test in 1998 that served as a basis for the development of the initial LUCID suite of C&I contained within it a mix of input, output, management process, and enabling condition indicators. During the CIFOR-NA test, an attempt was made to select indicators that were appropriate to the FMU scale.

Working more explicitly within a systems-based approach to monitoring sustainability, the CIFOR-NA test C&I were reviewed and reevaluated. Although the concepts contained within the CIFOR-NA management process and enabling condition indicators were viewed as important and related to achieving sustainable outcomes, the LUCID core team did not feel that within the context of the Forest Service with a strong set of laws, policies and regulations that these types of indicators: a) were best measured at the FMU scale; b) would vary significantly enough over time or space; or, c) were useful measures to characterize the state of the systems. Some of the management process or enabling condition parameters were retained because they were the best proxy measures available (e.g., public participation indicators and the genetic selection indicators).

Subsequently, guidance was given to the LUCID forest teams that most indicators and measures within the LUCID Project would be focused on outcome measures although input measures, enabling condition measures and management process measures should be considered, particularly when used as proxy measures.

Throughout the test, the LUCID forest teams had the ability to accept, modify, delete, and add indicators and to develop measures for these parameters. This provided an opportunity to examine in more detail the utility of input, management process, and enabling condition parameters within a systems-based approach to monitoring. Most of the LUCID forest teams included some management process or enabling condition measures in their final lists. Consistent with the initial LUCID core C&I set, enabling condition type measures of public participation/collaboration and of genetics were common to most of the forest teams. Additionally, several teams added measures of the completeness of inventories to their suites of C&I. The Blue Mountain Province Team included a very broad range of management process measures in their list of C&I although all of these measures might not have been included in a prioritized list. Throughout the LUCID Project, forest teams explored a number of interesting questions or issues regarding enabling condition/management process parameters.

Management Process or Enabling Condition Parameters as Proxies

In the absence of trend data for a monitoring parameter that measured the state of a component or interaction of a system, some participants felt that an enabling condition measure might provide a more direct link between management activities and the outcomes of sustainability monitoring. For example, nonnative seed stock can result in significant effects on the structure and function of ecological systems and cascading effects on economic and social systems. In the absence of available data, trend data, or cost-effective methods for monitoring nonnatives, monitoring the extent to which nonnative seed stock rules are enforced may provide some indication of a potential problem.

Similarly, the presence of a fine-scale forest vegetation inventory classification system (e.g., ecological land typing) may assist management of ecological systems. While the presence of detailed classification and mapping is not a predictor of good ecosystem or landscape structure or function, it does perhaps provide some measure of informed management actions that have been taken or could be taken in a specific area to help achieve sustainability.

Outcome Measures Do Not Accurately Reflect the State of Management

Some LUCID team members or forest supervisors expressed concern that while the outcomes of sustainability monitoring may reflect the state of the forest they do not necessarily reflect the state of the management. In the eastern United States, for example, past forest use on lands now within the national forests system yielded national forests that can be best described as forests in recovery. In these cases sustainability monitoring can provide very useful information on the state of the system to inform a recovery plan as part of a regime of adaptive management. It would not, however, reflect the current state of the management of the forest. That is, in some situations forest management may be making substantial progress in affecting change via restoration of the state of systems though the current condition of the forest may still be substantially impaired. Consequently the outcome indicators may still not be attaining the desired standard. Given this scenario, some forests may want to include additional measures of management process to closely track management actions in order to tell a more complete story of sustainable forest management.

Monitoring Enabling Conditions and Management Process is Still an Important Task

LUCID forest teams and LUCID forest supervisors felt that there was an important, but limited, place for enabling condition and management process indicators in monitoring. In the case of broader enabling condition indicators (e.g., funding support, currency of management plans), most recommended that monitoring would be more useful at a larger scale (Chapter 14). Much of the management process or action monitoring is more closely allied with the implementation monitoring already ongoing within forests. Making a stronger linkage between implementation monitoring and sustainability monitoring, through common use of a systems framework, was suggested as a way to provide more value for management (Chapter 14).

Based on the experience of the LUCID forest teams, there were nine management process and enabling condition measures (Chapter 11) included in the final LUCID core C&I set[1]. Where these measures served as the only feasible assessment method identified for an indicator, they were included as "recommended measures" in the core C&I set (three recommended measures). Six measures were included as "optional measures" in the core C&I set, because they were not considered crucial or applicable by all forest teams

Indicators of Interrelationships

Sustainability is the result of the interacting ecological, social, and economic systems; so not only do we need to monitor the components or parts of the systems but also the interactions between and within systems. The discussion and exploration of how to ensure that a sustainability-monitoring program truly captures the interrelationships necessary to assess sustainability was a topic of frequent discussion in the LUCID Project. LUCID participants commented throughout the test that while they felt progress had been made in moving towards a sustainability monitoring program they weren't sure that it was yet truly probing the interrelationships. Based on the experience and discussions of the LUCID forest teams the core team reexamined this issue of integration and integrative indicators within the discussion that follows.

Are integrative indicators different or do we achieve integration through synthesis?

The discussion starts with the questions that frequently surfaced during discussions with LUCID participants:

- Are sustainability indicators by their basic nature addressing interrelationships?
- Are indicators of interrelationships something different than what we have been focusing on?
- Does a systems framework inherently lead us to indicators that help synthesize?
- Is the function largely accomplished through the synthesis and analysis process—either the technical analysis stage (Chapter 13) or through the process of decision-making and discussion?
- What role does the establishment of reference values have in examining interrelationships?

The core team's conclusions are that interrelationships are a result of a combination of all of the above. As our collective experience with monitoring and understanding sustainability grows, we are sure there will be other perspectives and ideas that enhance the discussion here; however, these are our preliminary thoughts on the issue.

---

[1] According to the nomenclature of the Tropenbos Foundation most of these measures were best classified as *management process* parameters. Given that only a couple of *enabling condition* measures were included in the final suite of recommended measures they were kept within the principles and not separated out.

Systems Interactions

Initial examination suggests that the selection of C&I will inherently consider interactions as we are selecting indicators of the various attributes of interacting systems. Where human systems are more dependent on ecological systems (e.g., forest-dependent communities, developing nations), all of the indicators of human systems would indeed be indicators of interaction. As human systems have become more global and less immediately reliant on natural resources, the type and extent of the interactions and relationships between human systems and ecological systems has changed. The globalization phenomenon even when expressed at small spatial scales (e.g., communities or states as "trade") has resulted in interactions between human and ecological systems that frequently occur at broad range of spatial scales. For example, the communities around Ottawa National Forest may consume timber products in the form of paper; but the fiber that produced the paper may come from trees that were harvested in British Columbia and processed in Seattle. Alternatively, the black cherry harvested on the Allegheny National Forest may be in response to German demands. Currently communities are (apparently) less reliant or directly dependent on our natural resources (local or otherwise) for all aspects of life—from synthesized pharmaceuticals to knowledge-based high-tech jobs. Consequently, the relationship of human systems to natural systems is much less direct.

This dilemma was forefront in the discussions at the forest level where LUCID forest teams spent a great deal of time considering the relationship of the social and economic systems with respect to the national forests. Clearly the issue of how tightly one system is bound to the other is a big issue and the questions that arise include: What should count or be included in terms of the forest's responsibility? What affects the forest? There are no definite answers, of course. From place to place the nature and tightness of the relationship between the forest (national or otherwise) and human systems varies.

> *"Sustainability of ecological and social systems is not only a matter to be evaluated within a hierarchy of the same system but also between kinds of systems. The means by which those interactions are described involve the same structure and function attributes that occur within a system, except the focus is on variables the interacting systems have in common. An explanation for systems therefore needs to also acknowledge that there are structures and processes that provide for interaction between ecological and social systems. ... Humans are the archetype organism for understanding the interaction between social and ecological systems. Processes within social systems are almost exclusively human processes. For example, both families and communities are highly interactive with various ecological systems."*
> *(Hoekstra et al. 2000)*

Most LUCID forest teams took a general approach of trying to focus on the subset of social/economic systems that talked about the interaction between the human system and the ecological system. Most addressed the relationship in both directions: how did the forest affect socio-economic systems? and how did socioeconomic systems affect the forest? Within a North American context the extent to which human systems are bound to ecological systems, particularly within the same spatial scale, is relatively weak. The mental framework that most LUCID participants used when identifying indicators and measures was to select that subset of human systems measures that addressed how human systems interacted with ecological systems. Consequently the majority of socioeconomic indicators included within LUCID forests' tests were inherently about indicators of interaction with the ecological system.

A Subset of More Integrative Indicators

Moving beyond this broad-brush approach to addressing the issue of integration and interactions there is a subset of indicators that really have much more to do with interactions and can be used to examine system interactions more closely.

- **Environmental Justice**—The indicator of environmental justice and its associated measures examines who bears the cost of resource use and development and focuses on the equitability of interactions between human systems and ecological systems.

- **Stewardship Activities**—Participation in stewardship activities is a direct measure of the interaction, specifically investment, of local people into the ecological system.
- **Capital and Wealth**—Economic indicators of capital and wealth along with indicators of the yield and production of various goods and services are all about the extent to which human economic systems are interacting in a sustainable or unsustainable way with ecological systems addressed from a productive capacity perspective.
- **Landscape Patterns**—Measures for landscape patterns address issues of fragmentation and complexity. The Mt. Hood National Forest Team advocated an analysis approach using the HABSCAPES model, which examines the efficacy of landscape patterns for specific populations. These measures are examples of the integration within systems (e.g., landscape and population systems).
- **Community Trade Balance**—Analysis of a communities trade balance (e.g., value or volume of imports to exports) probes the globalization issue and the extent to which the human system at one scale is subsidized off production of ecological services at another scale.

These examples illustrate that there is a subset of indicators and their measures that focus more clearly on interactions between and within systems. In some other areas within the suite of C&I there is opportunity to develop better indicators or measures to further probe these relationships.

Integration Through Analysis

In a number of cases both within the subset of integration indicators (e.g., community trade balance) as well as for the broader set of indicators, a detailed analysis outside of the monitoring program may be required to flesh out the integration between indicators. For example, with respect to the indicator of community trade balance questions for analysis include:

- Is there a positive economic trade balance?
- If the trade balance is positive, is it positive because capital stocks are being depleted?
- If the trade balance is positive, is it positive because human capital is being depleted or imported?
- Are the costs of a positive trade balance the result of an externalities problem?
- If the trade balance is negative, who is bearing the cost?
- Can a negative trade balance be sustained and at what cost?

Although sustainability monitoring systems should hopefully provide data to answer many of these questions, in many cases additional data, analysis, or investigation will be needed to fully address integration issues. Analysis of these kinds of questions is a path that can be explored to provide meaning beyond individual indicator-by-indicator reports. In some cases there will be a need to build a more specific causation model for example, to really understand the interactions (e.g., to predict the interaction between soil erosion/loss and loss of productivity in terrestrial and aquatic systems). The Bureau of Economic Analysis (United States Department of Commerce), for example, has started experimental application to non-renewable resources and also to fisheries and timber as satellite accounts of the National Income and Product Accounts (NIPA) system. The intent of these frameworks is to examine interactions between economic and ecological systems in terms of flows and stocks. These are natural capital type accounting systems.

Analysis of the relationships between indicators and associated measures can be a further way to probe interrelationships and to add meaning to our understanding of sustainability.

Identifying a Critical Suite of Indicators: How many indicators are too many?

A Suite of Indicators

An indicator is a quantitative or qualitative parameter that is a sign or signal of the state or condition of something. Within the LUCID context, each indicator with its associated measure(s) (Chapter 9) gives a picture or signal of the condition of a component (structure) or interaction (function) of the ecological, social, or economic system. As systems are more than the sum of their component parts, (Chapter 2) so too are indicators. While each indicator can be examined to provide specific data about the parameter it is intended to report, the real value of the indicator comes from its contribution to the picture that is collectively presented by looking at a suite of indicators within a systems perspective. Monitoring indicators can be helpful in providing information about the state of systems for adaptive management; but an individual indicator, by itself, cannot be interpreted as sustainable or unsustainable.

Indicators and measures have a variety of different purposes from describing the state of a system to revealing key trends to predicting future states. Indicators and their associated measures are most useful when they can quantify information so that its significance is apparent and simplify information about complex systems to improve understanding (Natural Resources Canada 2000). The use of indicators is based on the assumption that monitoring the indicator is an accurate and more cost-effective alternative than monitoring many individual processes, species, or phenomena. Consequently, selecting the best indicators and measures is extremely important but also very difficult.

Indicators can be developed in a variety of ways from expert-based methods to full collaborative methods. The methods for indicator selection in the LUCID Project attempted to use a blended approach to build upon the strengths of many of the approaches and minimize the weaknesses. The process used, from the initial identification of possible indicators for evaluation by the core team, to the forest-based selection and testing of indicators to the final compilation of a recommended suite of a recommended and optional suite of indicators involved a series of steps directed at selecting the best indicators. Selecting indicators, particularly for a subject matter as broad and complex as sustainability, is extremely difficult. Although a variety of criteria were used throughout the process to help evaluate and select the best indicators, indicator development is recognized as an ongoing process that should be continued to refine indicators. Experience gained from repeated monitoring, the identification of critical gaps through analysis and interpretation of results, and the development of new methods to acquire information that make measuring other indicators possible are just some of the reasons why indicators may shift over time. Within a systems approach to monitoring, indicators can be added, deleted, or modified without deleterious effect on the entire suite. In this context it is the activity of monitoring the state of the system that is critical, not the choice of the individual indicator or measure.

Identifying a Critical Suite of C&I

Indicators collectively provide the meaning in a program of monitoring and assessing sustainability. The most frequently asked question is: How many indicators are enough to tell the story?

Some monitoring programs have taken a design approach of limiting, in advance, the number of indicators that can be developed. Some institutions have, for example, set an *a priori* target of identifying 10 or 20 critical indicators. In the LUCID Project step-wise approach was taken to identify, test, and select the best suite of indicators. Although the feasibility of implementing the resulting monitoring system must be evaluated, it was felt that applying a numeric constraint in advance would limit the identification of the best suite of indicators and restrict the test of the potential utility of sustainability monitoring at the forest management unit level. Our first priority for evaluation was whether the suite of selected indicators gave a relatively complete picture of sustainability.

What is the Concern About Numbers?

The concern about the total size of the suite of C&I centers on whether the resources are available to administer the resulting monitoring system and whether the results can be communicated. Administration costs of sustainability monitoring include 1) the fixed costs of the initial design of the monitoring system and the adaptation required at the forest and 2) the ongoing costs associated with repeated acquisition and analysis of monitoring information over time. Apart from the initial design costs, the following questions must be examined for the ongoing monitoring costs:

- Are some indicators more or less critical on a forest?
- How frequently do you need to measure each indicator?
- Can some indicators can be measured less frequently and still provide the needed information?

- Can common methods be developed to collect information on several indicators at once? For example, can a social assessment or social values survey collect information for many indicators?
- Can an adequate sampling scheme be identified for certain indicators to reduce monitoring costs while still providing representative data?
- Can efficiencies be gained by reconciling sustainability monitoring needs with other monitoring data needs?
- Can your partners provide some of the data required?

The size of the set of C&I also raises concerns about the ability to communicate the results effectively and simply both within the Forest Service and to the public. The more indicators there are, the more difficult it will be for various audiences to fully comprehend the substantial amount of information provided by the indicators or measures. For example, First Approximation Reports for many National and State C&I initiatives have produced extensive volumes of detailed indicator reports; and while these data provide important details for those involved in specific management initiatives or decisions, they are often too detailed for most audiences. Many of the other C&I initiatives have found that a mix of narrative and summary graphics is one way of communicating the results more effectively. Similar approaches were tested during the LUCID Project.

The systems approach used in the LUCID Project was selected not only as a way to help identify a better suite of C&I for monitoring but also to provide a model for analysis. If sustainability is about sustaining the context of the systems that support us, then monitoring indicators are useful to provide an indication of the state of each of these systems. The systems framework provides an organizing basis by which the results of the individual indicators and measures can be presented in a synthesized way. In addition, LUCID forest teams found great utility in presenting their results in a narrative form by presenting 'stories of sustainability' related to management issues or specific audiences (Chapter 15).

Building, Screening, and Prioritizing Indicators and Measures.

The CIFOR-NA set of C&I served as the initial basis for the LUCID Project (Chapter 4 and Chapter 7). CIFOR-NA used 207 indicators with an additional 200 receiving an initial screening. At the end 54 indicators formed the basis of the CIFOR-NA suite of C&I. The LUCID core team developed a guiding systems framework and did a series of gap analyses based on the CIFOR-NA set of indicators and supplemental indicators from other locations and developed an initial list of 42 core indicators for consideration by the six forest teams in their evaluations.

The forest teams were given some standard guidance in the development of C&I that affected the overall size of the suite of indicators. teams were asked to take a systems approach to developing C&I; thus, while they could propose changes to the systems framework (at the criteria level), in theory, there would be at least one indicator and measure for each component of the systems frameworks. Teams were asked to keep the wording and concept of indicators broad enough that they might be applicable across the national forests system. Measures (Chapter 9) and reference values (Chapter 10) were included as separate layers in the hierarchy and not nested within indicators in order to facilitate broader application. They were also asked to try and design the optimal set of C&I to monitor sustainability and not to be restricted to what currently is monitored. Given that some elements are more complex than others and the difficulty in measuring these elements varies, any element (e.g., criterion) could have more than one subelement (e.g., indicator). (The implications of different numbers of elements within the C&I structure on analysis are discussed in Chapter 13.)

The development of the Forest's C&I was an iterative process. Teams were guided to include those things they felt were critical to monitoring within a systems context and then to narrow down the list afterwards. Some of the teams tried specific ways of scoring and prioritizing indicators (e.g., by examining rankings of the key indicator or measure within each criteria) or within each principle. For example, the set of ecological C&I for Mt. Hood National Forest was significantly pared down to identify a much smaller subset of indicators and measures that were considered of high priority. Other teams made a recommendation to undertake a comprehensive and structured prioritization exercise of their final C&I set, due to the fact that they did not have the time to complete this exercise by the end of the test.

Developing and testing indicators and comparing them between sets is a difficult process. Although the teams worked with the same set of definitions of terms and the same hierarchical divisions, there is always some variation based on the approaches. An average of 56 indicators was included in the six forest sets, ranging from a low of 44 to a high of 77 indicators (Table 20). Indicators were generally equally divided between the three principles although the economic indicators had consistently fewer indicators across all sets. The criteria, indicators, and measures tested by the forest teams were reviewed by the core team and the final recommended suite of LUCID indicators developed. It is recognized that individual forests may still want to add additional indicators and/or measures to this final set in order to address a concept that they feel is very important on their forest. The final LUCID recommended C&I suite contains 58 indicators (Appendix 10).

In a survey of other C&I efforts currently underway within the US[2], the Northeast Area Foresters reported that the number of indicators varied depending on the scope of the project. The average number of indicators across all initiatives was 60 with only three initiatives containing fewer than 20 indicators. In terms of the effort required to implement monitoring, a more important factor to consider is the level of effort that is required to acquire the necessary data to inform indicators (see Chapter 9 and Chapter 15).

Within a sustainability assessment detection is the primary concern; therefore, one needs to have the minimal set of indicators that provide complete coverage of all the critical system components because it is impossible to know *a priori* which component might fail. Since we are trying to detect future conditions without knowing the probability of their occurrence, monitoring all components is the only sensible strategy. The contention here is that C&I following a systems framework provides the most efficient coverage for sustainability monitoring and captures not only the components but also the emergent properties arising from their interactions.

---

[2] Sixty initiatives were included in the survey, however, only 39 had progressed to the point of indicator development and are thus included within the data.

Table 20. Comparison of Indicator Numbers Between Criteria and Indicators Suites

C&I Set	**Criteria**	**Total Indicators**	*Social Indicators*	*Ecological Indicators*	*Economic Indicators*
CIFOR-NA Final Set	16	54	*19*	*20*	*15*
LUCID Initial Core Set	18	42	*10*	*21*	*11*
LUCID Forest Tests					
Allegheny		49	*12*	*23*	*14*
Blues		44	*13*	*21*	*10*
Modoc		60	*20*	*27*	*13*
Mount Hood		54	*21*	*19*	*14*
Ottawa		50	*18*	*21*	*11*
Tongass		77	*23*	*38*	*16*
[Average]		*[56]*	*[18]*	*[22]*	*[13]*
LUCID Final Core Set	16	58	*21*	*21*	*16*
Montreal Process	7* (17)	67	*22*	*23*	*22*
CCFM	6* (22)	83	*20*	*44*	*20*

* The bracketed number represents the number of sub-criterion--the closest equivalent to LUCID use of the term criterion.

CHAPTER HIGHLIGHTS

- Indicators are simplifications of complex phenomena and are intended to provide small bits of information to reflect on the status of larger systems.
- The LUCID Project emphasized selection of short-term and long-term outcome-oriented indicators as a means of assessing the contexts, or systems, that sustain us, rather than on sustaining inputs or outputs.
- Six forest teams worked with a common suite of FMU-scale indicators to adapt, accept, or revise them to fit their situations. These indicators were then evaluated for utility across the range of conditions in the test forests to determine if there were common threads that could be examined consistently.
- A final suite of 58 indicators was selected as a common core set applicable across the range of conditions.
- The intent is that indicators developed following a systems framework provide the most efficient coverage for sustainability monitoring and capture not only the components but also the emergent properties of systems that arise from interactions.
- Synthesis of an evaluation of a suite of indicators is needed to provide information about the state of systems.

CHAPTER 9.

MEASURES AND DATA ELEMENTS

BACKGROUND: MEASURES AND DATA ELEMENTS 143

➠ *Summarizes the role and purpose of measures in the C&I hierarchy and their application in the LUCID Project.*

PROCESS: THE APPROACH TO DEVELOPING MEASURES 143

➠ *Outlines the process used to develop measures.*

THE LUCID EXPERIENCE WITH MEASURES 144

➠ *An overview of the measures developed for the LUCID Project, highlighting the detailed information available on the Resource Database CD; and discusses the different purposes for measures, the role of proxy measures, and spatial and temporal scale issues.*

APPLICATION IMPLICATIONS 148

➠ *Discusses issues related to the availability and adequacy of protocols, data availability and quality, and the use of corporate data.*

> *"Measures provide specific details or protocols that describe the way the indicator is measured in the field and include the source of information for the indicator; and the measurement method including the form, scale, timing, and units of data that are gathered are specified. Data elements are basic data that inform a measure."*
> (Lammerts van Bueren and Blom 1997)

BACKGROUND: MEASURES AND DATA ELEMENTS

Developing measures to assess indicators is a necessary part of actually implementing a C&I program; but few of the available sets of C&I, particularly those at the FMU scale, have well-documented measures (Woodley et al. 2000). While suggested means for measuring indicators were included in the CIFOR-NA test, they were relatively limited in scope and detail. Consequently, one of the principal tasks of the LUCID forest teams was to research and develop measures or means of verifying each indicator.

Forest teams were encouraged to use available and recognized measurement protocols if they provided the right kind of information at the right scale. However, we asked that teams not be driven by existing protocols or available data if these did not provide what was considered to be the best information for the indicator. Although measures (originally termed "verifiers" in the LUCID Project) did vary greatly from forest to forest, there were, in most cases, common approaches between the concepts that forest teams were trying to measure.

The development of measures not only included identifying useful protocols to assess the indicator but also involved consideration of issues such as data quality and consistency, spatial scale, the overlap, linkage, and ability to share information between measures, the sensitivity of the measure to change, and an assessment of data sources and availability.

Data elements were not originally anticipated as a hierarchical component in the C&I framework, but the need arose to specify and label data elements as the individual pieces of data that are used to inform the measure. This occurred because in many situations a measure is supported by two or more pieces of information (data). Data elements were an optional part of the C&I hierarchy; thus, for those measures that relied on only one piece of data, the level of data elements was not always needed. Because data elements were literally specified pieces of data associated with a measure, they are treated as part of measures throughout the rest of the chapter unless mentioned otherwise.

In addition to identifying data elements, forest teams were asked to specify the spatial scale and units of interest for data needs. For example, examining income on a community-by-community basis may be the best way to assess income distribution. As a result, there may have been a series of data elements (or measures depending on the analytical approach used by the forest team) representing income with one data element for each unique spatial unit/polygon (in this case each community). Consequently, while a single measure may appear to be informed by a single data element, the clear specification by each forest team of the spatial units of interest provides a more complete picture of what is often a fairly large list of data elements. These data may in fact have been provided directly that way (e.g., from the forests' GIS database).

PROCESS: THE APPROACH TO DEVELOPING MEASURES

The development of measures was a major task for LUCID forest teams. Those measurement protocols that were available came from a wide variety of sources (e.g., CIFOR-NA) and they were developed at a variety of spatial and temporal scales. Existing measurement protocols from within the Forest Service were a valuable reference source; however, for the most part the forest teams relied on their own "professional experience and knowledge of available data and customary metrics" (Ottawa National Forest Team).

Teams noted that they frequently had brainstorming discussions about what question the indicator was truly trying to answer, and many participants found it very useful to document these specific questions. Based on these questions, "[p]ossible important aspects of the issues were explored and evaluated to see if there were elements that contribute to measuring that indicator" (Blue Mountains Province Team). The teams noted that they tried to pick measures "currently in use in day-to-day operations, ones that are required under current forest plans including monitoring plans" (Blue Mountains Province Team). Current forest plan monitoring activities and other forest-specific initiatives (e.g., watershed analysis) along with regional assessment processes provided excellent sources of possible measures.

Based on the experience and recommendations of the individual forest teams, the core team worked to identify a minimal set of best measures to fit the final list of C&I. The process of researching and selecting measures, as with other steps in the process, was a further way for forest teams to clarify, refine and prioritize indicators. This stage in the process also involved teams looking in a somewhat more systematic way at Forest Service measurement protocols and data, forging new relationships outside the Forest Service to find additional sources of data, and conducting gap analyses of existing monitoring programs.

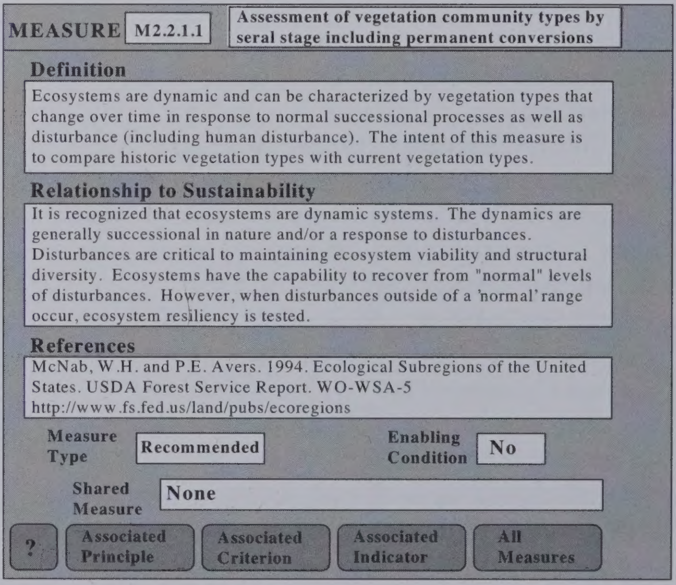
THE LUCID EXPERIENCE WITH MEASURES

The LUCID Measures: Ecological, Social, and Economic

Although a minimal amount of reference information was available to them, forest teams focused much of their time and effort on developing measures. They selected, developed and evaluated measures documenting each with a description, the relationship to sustainability, measurement details, data quality, data source, and availability among other attributes. These initial measures and their evaluative and descriptive information formed the basis for the selection of a suite of measures as part of the final suite of C&I (Chapter 11).

For the 58 indicators included in the final selection, there are a total of 119 recommended measures including 36 social measures, 45 economic measures, and 38 ecological measures (see Appendix 10). These measures are supplemented with a small set of proxy measures frequently used by the forest teams and a set of optional measures that probed aspects of indicators that were thought to be of potential interest in specific locations but have less general applicability. A measure-by-measure review of the details and evolution of each measure from all six forest teams would be too extensive to include in this report. Indeed it is difficult to even convey the meaning of a measure through a simple name. As a result, a working database was prepared with the information provided by the forest teams (Figure 20). The LUCID Resource Database contains detailed information on each of the selected measures (see the database description in Chapter 11 and find the database in Appendix 9).

The next parts of this section provide some broad highlights regarding the nature and type of challenges encountered by forest teams with developing and finding data for measures.



MEASURE M2.2.1.1 Assessment of vegetation community types by seral stage including permanent conversions

Definition

Ecosystems are dynamic and can be characterized by vegetation types that change over time in response to normal successional processes as well as disturbance (including human disturbance). The intent of this measure is to compare historic vegetation types with current vegetation types.

Relationship to Sustainability

It is recognized that ecosystems are dynamic systems. The dynamics are generally successional in nature and/or a response to disturbances. Disturbances are critical to maintaining ecosystem viability and structural diversity. Ecosystems have the capability to recover from "normal" levels of disturbances. However, when disturbances outside of a 'normal' range occur, ecosystem resiliency is tested.

References

McNab, W.H. and P.E. Avers. 1994. Ecological Subregions of the United States. USDA Forest Service Report. WO-WSA-5 http://www.fs.fed.us/land/pubs/ecoregions

Measure Type: Recommended

Enabling Condition: No

Shared Measure: None

Figure 20. Sample of a Portion of an Entry for a Measure in the LUCID Resource Database

Measures for Different Purposes

In the broadest sense measures are supposed to provide meaningful and valid information to reveal the state of an indicator to be compared against a particular reference value. Beyond this, however, the observations that come from measures may be differentiated by the variety of intents expressed by different observers. For example, the Ottawa Team noted that for each measure of an indicator, or for each set of indicators, they wished to draw three different types of observations: (1) the contrast between short-term and long-term outcomes of structures and functions to focus on intergenerational aspects; (2) the spatial distribution of effects over the entire FMU versus more localized effects (distribution); and (3) individual versus societal effects (e.g., equity issues). Addressing these different perspectives sometimes entailed developing multiple measures for a single indicator or multiple data elements for a given measure.

Measures for Different Purposes

"For example, we can address how current Ottawa timber output is helping to maintain the present economy as well as how the growing acreage of forested land and annual timber volume growth on Ottawa lands provides expanding opportunities for the future. We can address the importance of an expanding set of recreational opportunities on the Ottawa to the western Upper Peninsula, but also that the location of those facilities is critical to local areas. We can also discuss both our attention to creating and maintaining jobs in the timber and recreation sectors of the local economy as well as attention to individual needs such as special uses."
(Ottawa National Forest Team)

In developing their measures each of the forest teams explored the different ways that measures might be interpreted, often finding that even within a team a variety of different views emerged. What was problematic was when the intent or approach taken in developing measures varied from indicator to indicator or team member to team member with no conscious effort to explicitly determine the purpose of the observation or explanation of the different intents or approaches taken. *A priori* discussions with team members regarding the intent or purpose of the measures, or starting with a specific statement of direction is recommended. In the review process participants concluded that in the future a more explicit approach was needed to document the purpose of the observation with some consistency suggested both within a forest's efforts and between forests' programs.

Proxy Measures

LUCID teams were asked to design their preferred set of measures for the indicators and then to assess whether or not they currently could use those measures. In several situations forest teams found that using the preferred measure was not an option in the short-term because of insufficient available data, lack of information to inform setting a reference value, or lack of a feasible cost-effective protocol. Under these circumstances forest teams were encouraged to develop or use proxy measures until more adequate measures can be developed or used.

Although proxy measures were selected as temporary alternatives, there were questions about how accurate the proxy measures were. The Modoc National Forest Team illustrated this in their report, stating that the "Best Management Practices are a proxy for absolute measures of water quality, but we really don't know how good a link there is between BMP effectiveness and water quality measures."

The Use of Proxy Measures

"[W]e hoped to evaluate stand level disturbance from wind-throw (denoting both climate change resulting in more severe weather and management effects possibly increasing or decreasing wind-throw frequency), ice storms, or insects, but we did not have data. Therefore, we used insect-damage and storm-damage salvage sale acreage as a proxy...Chronic or systemic disturbance included data elements for deer herbivory...Since we cannot yet map our deer-over-browsed areas, we used an SOR to deer density as a proxy."
(Ottawa National Forest Team)

The use of proxy measures was a very useful way to continue the process of sustainability monitoring with less than perfect information. Many forest teams used professional assessments in these circumstances.

Incorporating Time into Measures: Sustainability for How Long?

Forest teams recognized that consideration of both short-term and long-term time scales was important to sustainability discussions, but they also indicated that this was an area that needed further work. The Blue Mountains Team for example noted that "few data elements that have to do with changes over time are being collected."

The Allegheny Team did a rough analysis of data used in the suite of C&I for which they were able to collect data during the test. They determined that approximately 60 percent of the data elements had data from one year, while another 20 percent contained 2-5 year averages or evaluated the percent change over time from 2 to 5 year periods, and the final 20 percent had 10 year averages developed, or the percent change was measured using 2 points from a 10-year period. Although a measure could be defined to directly incorporate change over time, in many cases the temporal dimension was addressed through the reference value development (Chapter 10).

Examples of Measures Incorporating Temporal Scale

- *Soil organic matter percentage change from baseline time period*
- *Percent change of timber sold in 5-year average (MBF and value)*
- *Change in asset value of mills during a given time period in the 4-county area*
- *Trend in average educational level of labor supply by subsector in forest-related industries (5- and 10-year intervals)*

(Allegheny National Forest Team)

Measures and Spatial Scale

The spatial dimensions of sustainability are as important as the temporal ones. While the intent of the LUCID Project was to develop a monitoring program for assessing FMU-scale sustainability, results for C&I that are not spatially differentiated within the FMU may not be particularly useful. The C&I approach fulfills two needs: (1) it can be used to assess sustainability of an FMU both locally and within a regional and national context; and (2) it provides sufficient detail to direct local-level forest management. If through monitoring an indicator is identified that does not meet the desired reference condition, the first questions that will be asked are: Where is the problem and why is it occurring?

Determining the appropriate scale at which to report information involves first considering the system properties of the indicator and secondly identifying at what scale the measure is meaningful. This includes assessing whether data are available at a scale appropriate for analysis. It also includes considering the balance between providing too general a set of results compared to one that may be too complex. The intent of the LUCID Project was not to merely repeat all of the detailed, often site-specific information, that the forests might have but rather to provide meaningful information to assess the state of the forests' systems.

National forests vary greatly in size and in ecological and socioeconomic complexity, and the scale of information required for decision-making consequently varies. LUCID forest supervisors and forest teams called for forest-level flexibility in determining the spatial scales of analysis appropriate to characterize each forest.

Within the pilot test, forest teams found that a spatial aspect to measures and their associated reference values was very useful. In many cases, because of the pilot nature of the test, data were

Examples of Measures Incorporating Spatial Scale

- *Proportion of tax base derived from transfer payments by county*
- *Recreation management expenditures per recreation visitor day by area of land within each recreation opportunity spectrum class*
- *Erosion on timber harvest areas by land-type*
- *Percent of each 5th field watershed with </= 1 stream on Forest Service lands on 303(d) list*
- *Change in scenic integrity and landscape character ratings by landscape unit*

(Blue Mountains Province & Allegheny National Forest Teams)

only available at a specific spatial scale (e.g., forest wide) although the team may have identified a different scale (e.g., by watershed or by community) as more optimal. In some of these cases new measures or new sources of data may need to be identified to ensure a match between the spatial scale of interest and the measure. For example, a great deal of socioeconomic data came from census or county level information; and while in some cases county-based geographic units may have meaning to specific questions, many forest teams found that the information would have had more rigor and meaning if it had been community based. This realization may result in the need for identification of alternative measures or sources of information or it may simply result in different analysis. For example, analysis of IMPLAN data has normally been completed only at a county level resulting in what some forest teams found was an inappropriate representation of data across a broad spatial area. Analysis of IMPLAN data based on ZIP code divisions is possible, however; and this may allow forests to use existing data and group it to more closely approximate the spatial scale best associated with their requirements.

Through the LUCID Project forest teams found that identifying the spatial scale for reporting and analysis was a critical decision to be made prior to the full development of the measure. When the spatial scale of interest was identified, multiple measures or multiple data elements were often required in order to organize the information. To help in information management and in analysis of data, the LUCID Project adopted a spatially explicit means of organizing and analyzing C&I data and reference values (Chapter 13). This geospatial approach to C&I assessment is very unique; and although there were some substantial challenges involved in developing this tool, teams found that a spatially related method of monitoring and assessing C&I was a critical aspect of a tool that could aid forest management.

The Use of Indicator Species

Typically, monitoring programs have focused on particular species, usually animals. Although an indicator-species approach can be very useful, there are a number of associated challenges, not the least of which is that the focus of monitoring often becomes the species itself instead of the ecological structures or functions that are necessary to sustain the indicator species.

The LUCID Project use of a systems-based framework started with the identification of the kind of system (e.g., organism) and the structures or functions associated with the system to be

Using Select Species for Monitoring

Ottawa National Forest—Gene Flow Indicator

"As population size and reproductive success were suggested in the indicator, we used data elements addressing these factors for a set of species for which there are, or may be, genetic concerns. Consideration of genetic effects is not common in Ottawa National Forest management, except for tree improvement programs. There is very little information available as to what species may be subject to genetic impacts from management or other factors. We selected aspen since there are regeneration concerns and since this tree is clonal; we thought there could be genetic impacts if particular clones were not perpetuated. We picked red-backed salamander since the Regional Geneticist, Dick Meier, suggested herps as a group that tends to have genetic bottlenecks and reproductive concerns, e.g., populations isolated by roads and timber management. We picked Botrychium matricariifolium *(daisy-leaf Moonwort, a small fern) since this genus includes several rare taxa, has unusual reproductive patterns and life cycles, and has been a topic of much attention on the forest. We picked Blackburnian warbler since it is a neotropical migrant bird that needs specific forest conditions, and is representative of this group of birds that are subject to worldwide population declines. Last, we picked wood turtle for similar reasons as the salamander and because it is a State species of concern. For each of these five species, we created data elements asking:*

1) *What is the change in the range of the species (precipitous decrease could spell genetic problems)?*
2) *Is regeneration adequate to maintain the populations on the forest (if not, small, isolated populations may result, with genetic changes possible)? and*
3) *What percent of forest populations are subject to inbreeding due to insufficient seed or parent sources?"*

(Ottawa National Forest Team)

monitored (e.g., gene flow). The monitoring of a system requires, however, a targeted strategy of indicator and measure selection to make the monitoring program both manageable and meaningful. In many cases protocols were suggested that measured the structure or phenomenon directly instead of inferring it based on a requirement of a species.

However, in a number of cases measurement was best achieved by targeting a specific species or selection of species. In this case the design of the measure first involved careful definition of the component to be studied and then the development of a set of decision-making criteria to select species to help indicate the condition of the ecological component. At that point forest teams strategically selected a set of species that were considered suitable as measures and that could be used as bellwethers of the ecological component under focus.

APPLICATION IMPLICATIONS

The Availability of Existing Protocols

For many ecological indicators there was a ready supply of sources for measures and established or standardized protocols. Socioeconomic measures, however, were much harder to find. Careful review of the indicators did help to specify a list of possible and needed measures. The process of trying to figure out exactly what to measure was one of clarifying the real reason for the indicator. "For example, in examining economic welfare we could focus our attention exclusively on an improving unemployment rate and be unaware of the possibility of a lowering per capita income and increasing number of households below the poverty line. Or we might focus our attention exclusively on growing employment income but fail to recognize the possibility that transfer payments occupy a growing proportion of total income, or that an individual economic sector is increasingly dominating the local employment market" (Ottawa National Forest Team).

Within the economic sphere some forest teams noted that although measures and data were typically available to assess the physical stock or flow of traditional Forest Service marketed goods and services (e.g., timber) there were not available protocols or data sources to support assessment of the quality and value dimensions of these goods and services. Measures to assess nonmarket goods and services were not readily available. Team members also noted that while there was a large quantity of socioeconomic data available from sources other than the Forest Service it was often at the wrong geographic or temporal scale.

Several forest teams noted that for social indicators related to the more intangible aspects of the social system (for example, sense of place, community and cultural identity, social cohesion, stewardship capacity and subsistence use) measures and protocols are not widely known about or accessible.

In some areas forest teams noted that while there was an established protocol (e.g., FIA air quality lichen monitoring protocols) that would provide the required information the data were not currently available for their forest and the establishment of a collection program for this information may be cost-prohibitive. If further examination of the associated indicators and measures suggests that these data are important to monitoring sustainability, then additional research might be directed at developing more cost-effective monitoring protocols or the forest may justify sufficient budget for future monitoring efforts.

Frequency of Monitoring

The frequency of monitoring for specific measures varies from data element to data element and depends on several factors: the sensitivity of the measure in detecting change; the level of accuracy, precision, and sampling adequacy; the opportunity to use common methodologies to simultaneously collect data for multiple measures; and cost factors. For some indicators monitoring may be very frequent, (e.g., seasonal measurements); but, for others periodic monitoring every 5 years may be adequate to detect change. Most of the LUCID forest teams did not fully complete an assessment of the suggested time frames for monitoring; and while a broad assessment of frequency of monitoring associated with the recommended core suite of PCIM has been completed, (Chapter 11) additional work and adaptation to local forest needs will be required.

One suggestion from forest teams is to determine monitoring frequency based on an initial assessment of baseline data for indicators against reference values. Where the data suggest there are no concerns, monitoring frequency may be reduced.

Data Availability and Challenges

Use of Existing Data

At the outset of the LUCID Project, forest teams were advised not to develop a suite of C&I that was based solely on what information was already available. The core team feared that with this constraint the best suite of indicators would not necessarily emerge. As teams progressed to the stage of developing measures for analysis, however, they looked increasingly at available data sources. A part of the test involved populating (to the degree possible) the forest's suite of C&I with available data, analyzing the data, and then reassessing the utility of the selected indicators and measures. Where the available data did not provide precisely the right information for a measure, forest teams were encouraged to continue to use the available data as a proxy for the preferred information. Consequently, five different scenarios emerged in relation to data availability:

1) Data of the right type and scale were identified and available to support a measure/ indicator;
2) Partial data (e.g., some but not all of the data elements) of the right type and scale were identified and available to support a measure/ indicator;
3) A data source was identified but there was insufficient time to obtain or process the data as needed;
4) Preferred data were not available but a proxy source of data was identified and used during the testing process; and
5) Data were not available or were judged as inappropriate to inform the measure, and the measure and data elements were retained in the suite of C&I as a placeholder to establish priorities for future work.

In general forest teams found that existing information residing within the forest's GIS database and annual forest monitoring reports were a source of much data, particularly ecological and economic data. Several forest teams were also able to access data from regional assessments (e.g., ICBEMP, SPAM) to supplement forest data and provide more regional information. Other common sources of data are listed in Table 21.

Table 21. Common Data Sources Used by LUCID Forest Teams

Common Ecological Data Sources	Common Socio-Economic Data Sources
Stand exam data	IMPLAN
Timber type mapping	Permit data
Ecological classification system mapping	Budget reports
Soil study plots	Forest Service accounting reports (e.g., INFRA)
Timber sale records	Census data
Roads mapping and records	County and municipal data
Breeding bird censuses	State Police
Botany field surveys	OSHA
Watershed analysis	Timber sale records
Wildlife management indicator species population trends	Research data from partners (e.g., universities)
State department of natural resource game species records	
EPA ozone and other pollutant records	
National Weather Service precipitation and climate records	
USGS hydrograph data	
USDA Forest Service Research Branch data such as FIA	
Research data from partners e.g., universities	
USDA Forest Service Research publications	
Subject matter experts' opinions	

Use of Corporate Data

The Forest Service and other government agencies maintain various data systems that provide a range of services from data collection through, in some cases, reporting and analysis. These corporate data sets cover a broad range of spatial scales including both national scale data and national systems that maintain a wealth of site-scale or project-level data for the entire United States (e.g., FIA, NRIS, IMPLAN). While each of these programs has a specific purpose and intent, if a match can be made between the information needs of FMU-scale sustainability monitoring and these corporate data sets, they can provide direction for establishing standardized methods of collecting or storing data for FMU-scale sustainability monitoring.

Throughout the process of developing measures to assess indicators, forest teams were asked to identify and document the potential or actual sources of data including any corporate data sets. Individual forest team's data collection and analysis for the LUCID test were, of course, based on their own individual suites of C&I and not the final list of recommended C&I. They did however make a series of observations and recommendations that will be useful in final implementation. Although work remains to be done in investigating and pursuing the possible relationships presented within corporate data sets, a preliminary comparison of the final suite of C&I against some of these data sets was completed for this project. This section briefly describes some of these programs and their use during the LUCID Project; later sections of the report provide more detail on opportunities for strengthening ties between corporate data sources and FMU-scale sustainability monitoring (Chapters 11 and 15).

Forest Inventory and Analysis (FIA) Program

FIA is a national forests survey that reports on the status and trends in forest area and location; in the species, size, and health of trees; in total tree growth, mortality, and removals by harvest; in wood production and utilization rates by various products; and in forest land ownership. Part of the FIA program also collects information relating to tree crown condition, lichen community composition, soils, ozone indicator plants, complete vegetative diversity, and coarse woody debris (formerly part of the FHM program). FIA has been collecting data for approximately 70 years. Since 1998 FIA has been changing from a periodic approach (complete measurement of one state at a time, on a cycle) to a continuous approach (continuous measurement of 10 percent to 15 percent of all sample locations in all states, every year). The program covers all forest lands (public and private) within the United States. FIA is implemented as a three-phase sampling program. Phase one consists of remote sensing for stratification into forest and nonforest classes. Phase two consists of a nationwide network of fixed area sample plots with one sample plot every 6,000 acres, where they collect basic forest mensurational data. Phase three consists of a subset of 1/16th of the Phase two plots (one plot every 96,000 acres) where they collect the enhanced suite of forest ecosystem measurements. Program partners including national forests or states may, at their discretion, augment the base FIA program by increasing any combination of (a) the sample intensity, (b) the measurement frequency, or (c) the set of measurements on any given plot. In addition to the plot-based program, FIA also coordinates the collection of other information through a woodland owners survey, a timber product-output survey, and through on-site logging utilization studies.

Several forest teams looked to FIA data as one source of information primarily for ecological structure and function indicators. Most found that

> *Use of Systematized Data Sources*
>
> *"We did not use any FIA data in our current model analysis, due to lack of time to investigate data availability and suitability. This is an area we would pursue in the future, if this sustainability-monitoring project continues. We did not use information from the NRIS modules since they are currently not installed and populated on the Ottawa National Forest. We anticipate that we will obtain input for our verifiers directly from these modules in the future and project that they will help to provide a standardized method of feeding values into the criteria and indicators model. We did analyze our forest GIS coverages and associated databases, including stands/ CDS (Combined Data Systems), roads, ECS (Ecological Classification System), ROS (Recreation Opportunity Spectrum), VQO (Visual Quality Objectives), streams, water-bodies, and watersheds, to provide values for several of the verifiers and data elements."*
> *(Ottawa National Forest Team)*

while many of the desired data elements were contained within the FIA program, the scale of data collection often did not match the data needs of C&I developed for the LUCID Project. For instance, "FIA inventory data can be useful at the landscape (forest or province) level, but there are not enough plots available to use it at the watershed (5th code watershed) level (especially after stratification) with any statistical validity" (Blue Mountain Province Team).

Forests that are part of a state or regional initiative to undertake a more intensive FIA sampling grid are able to benefit more from FIA data. For example, the Allegheny National Forest opted to intensify the phase three sample grid with completion of 160 sample plots on ANF scheduled for summer of 2001. The Allegheny Team noted that "using FHM [now FIA phase three] data from 93 plots inventoried over the past two years was helpful for several ecological verifiers (coarse woody debris and snags)," and that with the completion of more intensive grids "[t]hese plots will provide some nutrient-cycling measures." Chapter 15 discusses the potential for a strengthened relationship with the FIA program.

Natural Resource Information System (NRIS)

The Forest Service Natural Resource Information System (NRIS) is a set of corporate databases and computer applications that focuses on the biological, physical, and human features that make up national forest and grassland landscapes. NRIS consists of six resource information modules including air, fauna, vegetation, human dimensions, water, and terrestrial components. The NRIS program is currently under development with different modules at different stages of implementation and functionality.

Many of the forest teams indicated the desire to link their suites of C&I with the NRIS system, but most noted that NRIS was not yet far enough along to be fully usable. Once completed, NRIS modules may not only contain data that will be useful for FMU-scale sustainability monitoring, but the NRIS system is intended to be a repository for such data. A preliminary assessment of the linkages between the final suite of LUCID C&I and datasets within available NRIS modules has been conducted (Chapter 11). Based on these preliminary steps, there are a number of opportunities to develop stronger linkages between NRIS modules and FMU-scale sustainability monitoring (Chapter 15).

Ecological Data Overlap with Other Sources

"For the Tongass we relied very heavily on the extensive GIS database that has been built up in the last 15 years for the forest plan revision. We did not use plot data from FIA or NRIS in this iteration due to time constraints. Most of the FIA data is now available, but many of the data sets that will be used to populate NRIS are still in legacy form. They need to be brought into NRIS or made more easily available before we can use them in LUCID. The FIA data set has, however, only been collected twice on the Tongass and different methods were used each time. We would not be able to use it to monitor trends in vegetation differences until the next sampling period." (Tongass National Forest Team)

Impact Analysis for Planning (IMPLAN)

The Impact Analysis for Planning (IMPLAN) program is an analysis tool designed to help examine regional impacts on income, employment, production, and the natural resource base. Linking to a database of socioeconomic information, IMPLAN analysis can be performed at a range of scales from community to nation to estimate the impacts of projects, programs, policies, and economic changes on a region. The analysis can focus on describing trade, production, consumption, taxes, welfare and social security payments, savings and investment, debt, employment, and income. A variety of supplemental information from recreation and fish and wildlife expenditure profiles, to economic diversity indices, resource reporting financial data, and Forest Service transfer payments is also accessible through the IMPLAN economic center maintained at IMI.

Forest teams were provided with a linkage to the IMPLAN center to help them address economic data requirements of their indicators. Lack of familiarity with the IMPLAN system and time and technical limitations in accessing assistance for using IMPLAN information did mean that not all teams were able to fully evaluate the applicability of the IMPLAN corporate system to FMU-scale sustainability monitoring. However, most teams noted that it did provide a strong source of potential information. Limitations noted with the use of IMPLAN data included issues on

IMPLAN

"IMPLAN was useful for determining changes in employment and income relative to natural resource production (timber, range, recreation, and budgets) from one time period to another. This input-output modeling would also be useful for providing information about the economic base, trade balance, imports and exports, investment expenditures, etc." (Blue Mountains Province Team)

the timeliness of data, transparency of methods, and consistency of analysis. Several forest teams also noted that the analysis completed at a county level did not meet their information requirements. Because it is now possible to conduct IMPLAN analysis at the community level (ZIP+4), this will overcome one of the limitations noted for IMPLAN data. A preliminary assessment of the linkages between the final suite of LUCID C&I and IMPLAN data has been conducted (Chapter 11). A more intensive examination of data quality limitations (e.g., timeliness, scale, accuracy) is needed, as are methods to make this information more accessible to forests that have limited access to economics assistance.

Data Availability and Quality Assessment

LUCID forest teams' assessments of the availability of data varied given the nature and scope of their individual suites of C&I, the comprehensiveness of existing monitoring activities and data sources on the forest (e.g., forest plan monitoring), and the time and resources they had available to look for additional data. Some forest teams reported up to approximately 70 percent data availability while others noted significantly lower amounts. These are some common observations about data availability and quality:

- The area most lacking in data was the social indicators although some of this data may have been available from sources outside the Forest Service but was simply unavailable within the time frame of the test.
- Time-series data were generally not available. Even within the economic data that the Forest Service usually has on record, time-series information must be gleaned from planning documents and is not in readily usable information bases.
- During the pilot test, data were generally only readily available for land in Forest Service administration. Although information was available for many of the data elements off-site, there simply wasn't enough time or adequate resources during the LUCID Project to put the data together in common formats and metrics.
- Where data were available there was often significant concern about the quality of the data and the appropriateness of the sampling strategy.

All forest teams noted significant concerns about data quality, including adaptation from sources that were at different spatial or temporal scales than desired or data only partially fulfilled the requirements of the measure. In many cases teams had concerns about existing data; but within the time constraints of the LUCID Project, they did not have the time or resources to thoroughly test data quality. Nor could they collect new data, with the result that they had no choice but to use existing data, in some cases retrofitting existing data to different uses. For example, some teams found that IMPLAN estimates were suspect and that from one analysis to the next results changed. Others

Challenges of Working with Existing Data

"The actual [measures] and data elements used to address each indicator were dependent upon available data and the familiarity of team members with these data. It was at this stage of the modeling process that we had to confront the inadequacies in our information base and the complexities of the real world. The inadequacy of our information base was evident in the many [measures] we had to defer for the time being due to lack of data. In terms of real world complexity, the challenge was to manipulate data elements such that they would clearly and accurately provide information relevant to sustainability. Here, we had to consider technical questions involving, for example, the use of ratio measures, moving averages, or more exotic manipulations of data elements. Also, error, bias and related data issues had to be taken into account." (Tongass National Forest Team)

noted that existing forest inventory data were less useful because there was "[n]o past levels of data to measure change over time" (Allegheny National Forest). Forest Service information on timber sales was universally related as very good.

Use of Expert Knowledge

Proxy measures, described earlier in this chapter, were frequently needed where data for the preferred measure were not available. The use of expert assessment of the status of a measure was a frequent means of constructing a proxy measure. The ability to include data based on expert assessments was something that all of the forest teams supported because it allowed them to capture expert knowledge and give at least a preliminary indication of the status of a measure. Many forest teams noted that while they did not do this during the pilot test, largely because of initial challenges in the weighting process, they could see the utility in building in a means of assigning a relative weight to the value of this information so that a weighting factor could be associated with the reliability of the information.

Expert Knowledge

"[W]hen quantitative data are not available, expert knowledge is very valuable, and expert knowledge may be of greater value sometimes even when data ARE available. This is because of the ability of the expert to synthesize and interpret multiple pieces of data and experience in a way not easily done through strict numerical data interpretation. We therefore used this feature a lot, and see it as an excellent tool to capture or synthesize information that otherwise isn't available."
(Modoc National Forest Team)

Modoc Ecological Data Source Assessment

"Major ecologic data sources were Forest Inventory and Analysis data (FIA), Modoc Forest Plan, Sierra Nevada Framework, and local expert knowledge from inside and outside the agency. Many areas need further work to develop the best measurement methods and to avail existing data sources in the most meaningful way.

Data Category	Number	Percent
Data not available	20	11
Data but insufficient time	11	5
Poor data quality	5	3
Data obtained from expert knowledge	71	38
'Hard' data available and acceptable quality	80	43
Total data items	188	100

'Poor data quality' items were those that had to do with areal extent of vegetation cover types, and the amount of these that has burned. The vegetation cover data we have access to is very poor, to the point of being unusable. This is because data available in the two coverages we have are incompatible even though they purportedly measure the same thing. In 1978 vegetation type data were collected in Region 5 (mostly for timber purposes...nonforest vegetation has always been neglected in these inventories) by aerial photo interpretation with ground-truthing. The coverage was redone in 1995 via classification of remote-sensed imagery, and the results are quite different. It's therefore impossible to compare acreages of western juniper, for example, between 1978 and 1995.

'Data, but insufficient time' items included those that are available from the regional insects and disease group who have up-to-date information on extent and amount of forest mortality from annual flights, as well as estimates of the acres at risk from bark beetles by forest. These data would be easy to acquire. ...

'Data not available' items included those having to do with photosynthesis and carbon sequestration. Estimates of carbon sequestration and photosynthesis can be obtained from remote-sensing tools available at the national level, but we at the local level do not know how to do the analysis plus we don't have the necessary tools. This would have to be contracted with knowledgeable parties. The FIA GRID plot data were a major source of ecologic data, providing 14 items (7%). The Remote Sensing Lab GIS coverages of CALVEG vegetation types and structural and density classes accounted for 23 data items (12%). We did not use NRIS data as they are not available yet."
(Modoc National Forest Team)

An Evolving Set of Measures

Forest teams felt at the conclusion of the pilot that they still had too many measures and data elements and that there was a need for further screening. Teams suggested that spending more time "on the relative importance or underlying concepts of the measures would've potentially reduced the overall number of measures" (Blue Mountains Team).

Part of the advice given to the LUCID forest teams was that prioritization of measures would be aided by an initial evaluation of the data against reference values. Based on the experience of CIFOR-NA, the core team felt that the true worth of some of the measures might only be evident once their actual information value could be assessed. Given tight time lines at the end of the test, no forest team had the time available to engage a comprehensive post-data collection revision process. Despite this, many teams did make suggestions for revisions in their reports.

Core or Recommended Measures and Data Elements

Forest teams and forest supervisors recognized the need for both consistency and flexibility in what is measured and how data are collected throughout the Forest Service. This led to the development of a list of suggested best measures, while retaining a degree of flexibility in the application and interpretation of the measures to fit the unique conditions of individual forests. Based on the measures selected by the test forests, the core team identified a list of preferred or recommended core measures (including proxy measures) and a secondary list of optional measures that individual forests may find useful (Chapter 11). The final list of measures should be considered "recommended measures" only and not a prescribed list. Many areas need further work to develop the best measurement methods and to use existing data sources in the most meaningful way. It is envisioned, therefore, that the list of measures provided here is not the final list and that the refinement of measures will be an ongoing process.

> *"[Measures] changed with each iteration of the project, and we rejected many [measures] that were unworkable due to unquantifiable data, logistic constraints, or inadequate means of categorizing data. Likewise, at the data element and standard level we went through our list many times and found it most beneficial to write out the data calculations and standards for each [measure] to insure we had not overlooked something. This forced us to be more rigorous and ultimately enabled us to easily add things to the model."*
> *(Tongass National Forest Team)*

CHAPTER HIGHLIGHTS

- Measures provide specific details or protocols that describe the way the indicator is measured in the field and include the source of information for the indicator; and the measurement method including the form, scale, timing, and units of data that are gathered are specified.
- The process of researching and selecting measures was a further way for forest teams to clarify, refine, and prioritize indicators.
- There was a recognized need for both consistency and flexibility in what is measured and how data are collected throughout the Forest Service. This led to the development of a list of suggested best measures, while retaining a degree of flexibility in the application and interpretation of the measures to fit the unique conditions of individual forests.
- Based on the work of the forest teams, a suite of preferred or recommended measures (including proxy measures) and a secondary list of optional measures that individual forests may find useful were developed. The Resource Databook (Appendix 9—CD) provides detailed information for each measure.
- Corporate data sources (e.g., NRIS, FIA, IMPLAN) were used to varying extents by forest teams and will provide stronger potential sources for data acquisition and storage in the future; however, additional work is needed to ensure the required kind of data are available at the right scale.
- Many areas need further work to develop the best measurement methods (protocols) and to use existing data sources in the most meaningful way.

CHAPTER 10.
REFERENCE VALUES

BACKGROUND 159

Reviews the different types of reference values and discusses the potential shortcomings and merits of using reference values.

THE LUCID EXPERIENCE: THE ROLE OF REFERENCE VALUES 163

Discusses the experiences of the forest teams' work with reference values.

IMPLICATIONS FOR FUTURE USE OF REFERENCE VALUES 164

Discusses suggestions for a revised process for using reference values and a series of issues to consider when developing reference values, including sources, temporal and spatial considerations, and the utility of discrete and fuzzy reference values.

> "To evaluate and use indicators, it is often highly informative to compare status and trends measured by the indicator against some 'reference state'. Without such a baseline, it is hard to assess the magnitude of change objectively, whether the magnitude of change is important, or if any efforts at amelioration are succeeding."
> *(National Research Council 2000)*

BACKGROUND

What is a Reference Value?

Reference values come in a wide variety of names (benchmark, standard, trend, threshold, desired future condition, norm); but all refer to a comparison to which an indicator can be examined or gauged. The reference value gives a point of reference to help interpret what we know about an indicator; to force discussion about what the measurement of an indicator is telling us; to help us assess whether we are moving in the desired direction and at the right pace; and to help identify what other things interact with or are affected by that indicator.

The result of comparison against a reference value may, at the scale of an individual indicator or measure, trigger a range of responses including management action to correct an undesired situation, special cause-and effect-monitoring, intensified sampling, a change in a management standard/threshold or in the choice of the measurement protocol. Beyond the evaluation of the status of individual indicators, reference values allow the user to synthesize across a suite of indicators and assess the overall state of the systems compared to a desired target.

Reference values are the benchmark, standard, trend, threshold, or desired future condition against which measures are assessed. Reference values provide the means to determine movement towards or away from a desired target for any given indicator.

Reference values, although commonly used in other forms of scientific monitoring and in our everyday life from assessments of the economy to our health, are only beginning to be used in sustainability monitoring. In their assessment of a broad range of C&I initiatives, the Northeastern Area Sourcebook (Northeastern Forest Research Planners Association 2001) noted that six of the 39 initiatives included some form of reference values from broad benchmark-type statements consisting either of broad qualitative and directional statements (e.g., reduced rate of forest land conversion) to more specific time-oriented, quantitative reference values (e.g., conserve x percent land by x date). The Oregon Benchmarks program is one of the best examples of a benchmarking approach to reference values. When the terms and words used in indicators are examined a bit more closely, however, the numbers of initiatives implying the use of reference values is much greater. Many C&I initiatives define indicators with an implied direction.

	1998	2000	Page
KEY ENVIRONMENT BENCHMARKS			
Air Quality	A	A	63
Land Prevervation **Wetlands, Agricultural and Forest Lands**	A	B-	64
Salmon & Steelhead	F	F	67
OTHER ENVIRONMENT BENCHMARKS			
Carbon Dioxide Emmissions	**F**	**F**	**68**
Stream Water Quality	**A**	**B+**	**68**
Instream Water Rights	**A**	**A**	**68**
Timber Harvest		*new*	*69*
Municipal Waste Disposal per Capita	**F**	**F**	**69**
Hazardous Waste Site Clean-up	**A**	**A**	**60**
Heathly Wildlife Species	**F**	**D-**	**70**
Marine Species at Risk		*new*	*70*
Healthy Native Plant Species	**C-**	**D-**	**70**
Nuisance Species		*new*	*71*
State Park Acreage	**F**	**F**	**71**
AVERAGE OTHER GRADE	**C+**	**C-**	
OVERALL ENVIRONMENT GRADE*	**C+**	**C+**	

Figure 21. Summary Scores for the Environment Benchmarks for the Oregon 2001 Benchmarks Performance Report (Oregon Progress Board 2001)

Types of Reference Values

Reference values help us evaluate how we are doing; consequently, their utility critically hinges on the rationale for what we choose as the bases of these values. Reference values can be formed on a variety of different kinds of bases from current conditions to legal standards to historic range of variation (HRV). All present potentially logical foundations for forming reference values.

A variety of different terms are used to describe reference values. There is little consistency in the use of the terms, and they are not necessarily mutually exclusive. Initially during the LUCID Project, we adopted the use of the word *standard*. The forest teams suggested that *standard* had too restrictive of a legal interpretation and that a broader, more all-encompassing term was needed. After reviewing the range of options, LUCID participants recommended adoption of the more general term *reference value*. In any given suite of C&I the reference values may be or a combination of different forms or terms as explained below.

Thresholds

The maximum or minimum values of an indicator are its thresholds. They indicate the region of change in the value of an indicator beyond which precipitous declines will occur (e.g., an amount of habitat loss from fragmentation beyond which interior-dwelling species will not be able to survive). Identification of thresholds is very important because indicators do not necessarily progress in a linear fashion, but in reality few actual thresholds are known.

Benchmarks

Points of reference against which a measurement can be made and against which others may judge progress. Benchmarks can be quantitative or qualitative, input or outcome, short-term or long-term. The use of the term *benchmark* is fairly broad and may encompass a range of other kinds of reference values. Some view *benchmark* conditions as a set of intermediate conditions or points along the way to the desired future condition. Harwell (1999) notes that intermediary benchmarks may be particularly useful if, for example, the ecological condition is far removed from the desired condition and progress is focused more on restorative actions.

Reference Condition

Values that may be established based on reference to documented historical values (e.g., Historical Range of Variability) or on monitoring and comparison to nonaffected systems are reference conditions. Some people describe reference conditions as "bounding conditions," for example, a descriptor of a measure at each end of a spectrum from a high degree of disturbance to a high degree of pristine ecological condition (Harwell 1999).

Targets/Desired Future Conditions

According to Lammerts van Bueren and Blom (1997), a target is a "reference value to strive for." A target may also be a desired level to be achieved by an indicator. Further, a target by identifying the character of a desired future condition may represent that condition.

Norms

"A norm is the reference value of the indicator and is established for use as a rule or a basis for comparison. By comparing the norm with the actual measured value, the result demonstrates the degree of fulfillment of a criterion and of compliance with a principle" (Lammerts van Bueren and Blom 1997).

Standards

Any agreed upon value or measure can be regarded as a standard. They are frequently associated with forest plan standards. Standards may be legal or regulatory targets that must not be violated (e.g., human health water quality standards).

Trends

Reference values based on an assessment of trends look at change in data values over time and potentially at the rate of change. Maclaren et al. (1996) notes that trend indicators "provide only indirect information about the future, they are more useful for reactive rather than proactive policy-making. This is because a review of trend indicators can signal when corrective action may be needed, but they are poor at anticipating future problems, and cannot help us to design policies that will prevent these problems from happening in the first place."

Do We Need Reference Values?

The desirability and utility of setting reference values for indicators is an area that has been the subject of strong disagreement within the C&I arena.

Possible Shortcomings of Reference Values

Many people involved in the C&I arena advocate not using reference values–at most they suggest presenting data points on a trend line thus allowing people to draw their own individual conclusions about the state of an indicator. Some arguments for not using reference values—itemized below—may be related to their inherent challenges and may indicate areas to improve on if reference values are used.

Difficulty in Defining Reference Values

Reference values are challenging to set because identifying a threshold beyond which a structure or function cannot recover is exceedingly difficult. In part this is due to a lack of information; but more typically, it is a result of the fact that determining reference values is a subjective process. Given the difficulty and uncertainty in defining reference values, some people feel it is best to avoid them.

Subjective Nature of Reference Values

Since sustainability is inherently a values-based concept, the primary task is identifying what is to be sustained, for whom, for how long, and at what cost. Although there are certain thresholds (albeit hard to identify) beyond which recovery is difficult, many different states can be sustained if the appropriate energies (e.g., management action or resources) are directed to sustaining it. Setting a reference value to identify what level of a given indicator is to be sustained can seem to be too problematic, too inexact or imprecise, and too variable for some people to be comfortable with. Without reference values different people can view the same data and come to different conclusions. Often the hope is that with additional information or better science a precise, scientific, and objective definition of sustainability with associated thresholds will be readily identifiable. Given the values-based nature of sustainability, interpretation of results requires long-term and intensive participation by stakeholders, which may be difficult to perpetuate.

Challenge of Setting Standardized Reference Values

One critique of reference values cites the difficulty in standardizing them. This may particularly be the case when an identical set of indicators is used in a range of settings (e.g., application of Montreal Process C&I in a range of very different temperate forest countries). Although a standardized set of indicators may be developed that can be applied across a range of different environments, a standardized reference value (e.g., for acceptable soil loss) that can be uniformly applied from place to place cannot be determined.

For input-based indicators, enabling condition, or management indicators, it is much more likely that a standardized reference value can be developed. For example an indicator assessing the "presence of and conformity with seed transfer rules to minimize genetic mixing problems" or an indicator reporting on "compliance with Federal water quality standards" are relatively easy to measure from location to location and reference values can be fairly easily set and standardized.

For outcome-based indicators, however, standardized reference values are often inappropriate because they (and sometimes measures) must be specific to the ecological and socioeconomic system that they are associated with. For example, all forests may include indicators associated with fragmentation and connectivity; but the range of natural/historic variation and the functional effectiveness of fragmentation/connectivity varies by vegetation community type. While a reference value based on minimizing tolerance for interpatch distance to increase forest interior size in coastal temperate forests may be desirable the same reference value applied in the sage-juniper communities of the dry western forests may lead to significant aforestation of juniper resulting in loss of useful habitat, decreased water tables, and high fire risk.

Using Reference Values Implies a Determination of Sustainability

Some people interpret the use of reference values for indicators as implying that an individual indicator has an absolute value and that subsequently an absolute determination of sustainability can be made simply by summing up the scores of indicators in comparison to their respective reference values. The LUCID Project has taken the perspective that sustainability is an emergent property of the interactions and interrelationships between the structural and functional components of ecological, social, and economic systems. Indicators developed by looking to find the best measures of the components and their interactions must be interpreted together as a suite. The reference value merely initiates the discussion about the basis for the reference value, about the desired outcome for that indicator, and about the relative interactions between that indicator and others. Individual indicators and reference values are neither good nor bad but merely provide a signal to help inform the discussion of sustainability.

Merits of Using Reference Values

Based on the recommendation of CIFOR-NA and others, the initial approach within the LUCID Project was to attempt to include reference values within the C&I process. In spite of the fact that working with reference values was extremely challenging given the lack of documented approaches and models within other C&I initiatives, the LUCID Project participants found that setting reference values was an extremely valuable and necessary step. LUCID participants found that reference values, and the process of identifying reference values had a number of key benefits.

> *"Indicators will only work when they can be referenced against a target."*
>
> *(Woodley et al. 2000)*

Clarification

Discussing reference values helped the LUCID forest teams clarify what was being measured and why it was being measured. The reference value process frequently led to a reexamination of the measure and the question the indicator was addressing.

Identifying the Right Spatial Scale

The reference value discussion led to the clarification of the importance of spatial scale. The process of discussing what the range of acceptable values or thresholds were for an indicator brought clarity to whether or not there needed to be variation in the measures and reference value across different units. For example, could the same reference value be applied to adjacent counties, watersheds, or forest types or were different reference values needed?

Identifying Priority Measures

Identifying reference values for measures helped in further screening the key measures/ indicators. Sometimes the discussion at the reference value level led the group to conclude that the measure was not very sensitive to change or did not have high information value. In these cases it would be difficult to determine what would be sustainable and what wouldn't. If the conclusion reached was that any range of values might be acceptable as a reference value, it became clear that that measure/indicator was not very discriminating. Alternatively, in some cases, it was not possible to set reference values at this point in time; but the discussion of what the reference value would mean occurred at a broader, more theoretical level. If the conclusion was that the measure/ reference value was critical but that information was simply lacking at the moment, the LUCID forest teams would identify the measure and associated reference value as a high priority for further research or development.

Assumptions and Meanings of Sustainability

The process of discussing possible reference values for a measure helped bring to the forefront differing perspectives on the meanings or basic assumptions of sustainability. For example, in a discussion of reference values for an employment indicator some people advocated a reference value based on maintaining or improving the current rate of employment. Others advocated for a reference value that was based on a tolerance limit for change over time. These two perspectives represented fairly different views; and each side used the indicator or the reference value for a slightly different purpose: the first to provide a signal of employment stability for intragenerational purposes, and the second to interpret large fluctuations in change.

Temporal Dimensions of Sustainability

Discussions of reference values led to very explicit discussions on the temporal dimension to sustainability. Not only did teams discuss the time frame over which a change in values should be measured (for example to smooth out short-term variations), the discussion also often focused on the critical aspect from a sustainability perspective being the rate of change. Change, either positive or negative, was accepted for many measures; however, a high rate of change in either direction was indicative of a basic condition that the ecological or socioeconomic system would not be able to react to. Temporal scale issues with respect to the short versus long-term nature of outcomes, and inter- and intragenerational perspectives were also at the forefront during reference value discussions. The rate of change needs to be co-scaled such that large systems tend to change slowly and small systems more rapidly.

Identification of Mediating and Missing Measures

Discussions about the meaning implied by a given measure occasionally led to the identification of a missing and intervening piece of information necessary for understanding. For example, in preliminary discussions of reference values for an indicator of community trade balance participants identified that origin of labor was a missing component. In this context participants felt that while a community trade balance might be positive a positive reference value was not necessarily good if, a) the net balance of exports to imports was achieved by reducing the stock of natural capital (and that indicator/measure had been included); and/or b) labor was being imported to produce this net balance at the expense of investing in local labor sources. Labor source had not been included in the list of measures or data elements, so the teams suggested adding it as a measure.

THE LUCID EXPERIENCE: THE ROLE OF REFERENCE VALUES

Within the LUCID Project we were endeavoring to determine whether a suite of C&I could be developed to be used across a broad range of ecological and socioeconomic conditions. Indicators may be broadly applicable across different forest management units, but the meaning or assessment of the indicator would change based on the unique features and values of people within a specific place. Consequently, we chose to define indicators, generally, in a nondirectional way. However, we did feel that without engaging people in the discussion of what an indicator meant or implied, both individually and in consort with other indicators, sustainability monitoring could become simply another exercise in collecting data that did not assist decision-making. Although recognizing uncertainty on what and how to determine reference values, the LUCID Project incorporated an approach that involved moving from indicators to specific measures to reference values.

With respect to the development of reference values, LUCID forest teams received general guidance as to what a reference value might be, how it might be constructed, and possible sources for reference values. Some basic assumptions and thoughts guided our use of reference values in the LUCID Project:

- An assessment of a single indicator (or measure) by itself is only a partial signal of the state of a system—the suite of indicators together is more important.
- An indicator that does not meet the reference value is not necessarily ‘failing’ but is a signal for further investigation including of questioning the validity of the data and the appropriateness of the reference values.
- The interactions between indicators has to be examined to understand what a reference value really meant.
- Reference values might conflict with each other. There is no automatic process to resolve these inherent contradictions but rather they necessitate the discussion among different stakeholders.

- Reference values can be: 1) absolute and discrete (e.g., '1' or '2'); 2) qualitative (e.g., "yes" or "no"); 3) absolute within a range (e.g., <3, 3-5, >5); or 4) fuzzy (e.g., a ramped set of values representing a percent achievement of 100 percent true or 100 percent false.
- Individual indicators should not be interpreted with the terms *sustainable* or *unsustainable*. Instead, individual indicators simply either meet (or attain) the reference value or they do not. Sustainability is the state of the entire set of interacting systems.
- There is no known absolute state of sustainability that a given forest can be compared against. The assessment of sustainability is about engaging people in a discussion of the desired system condition.
- Although methods for developing reference values may be common from place to place the actual reference value differs based on the ecological and socio-economic situation and the values of stakeholders.
- If the same piece of information (e.g., road density) is used more than once within the suite of indicators, it should be able to have a different reference value in each place.
- Reference values may take a variety of different forms: legal *standards* (e.g., human health water quality guidelines); scientific *thresholds* (e.g., minimum viable population sizes for species at risk); management *benchmarks* (e.g., desired outputs of recreation visitor days); *trend* assessments (e.g., percent change in employment over time); preliminary *targets* (e.g., based on professional assessments).
- Reference values may not be able to be set for all indicators and measures during the initial phase of the project.
- Discussion about reference values often helps to clarify why the indicator is important.
- The rationale, assumptions, and data used to develop reference values should be well documented.
- Reference values are not static in nature but would change or shift over time with improved knowledge, changing conditions, and shifting values.
- The development of reference values ultimately requires an interdisciplinary and collaborative approach. Within the pilot nature of the test, the LUCID forest teams were not expected to be able to take this collaborative approach but recognized that reference values would need to be developed or ratified through some legitimate public involvement process (e.g., forest planning).

We realized that the development of reference values would be a very difficult task and one that within the test nature of the project the forest teams would probably not be able to complete; however, exploring the utility and feasibility of reference values was an important component. Forest teams became the real experts on reference value development. Each of the teams experimented with different approaches that we were able to compare at the end. None of us had any idea of the complexity and challenge involved in comprehensive use of reference values nor what exactly we would learn from the process and whether or how it would be valuable.

The following sections of this chapter provide some additional information about reference values and document some of the implications and recommendations for revising the approach to reference values based on the experiences of the forest teams.

IMPLICATIONS FOR FUTURE USE OF REFERENCE VALUES

Suggestions for a Revised Process

The process of developing reference values varied from forest to forest. Some forest teams were able to access literature or external resource specialists to help in the development of specific reference values while other teams had limited time for external consultations. A few forest teams started with specific discussions about the theoretical assumptions behind reference values within a sustainability context. Most forest teams intended to develop or review the reference values in an interdisciplinary forum but indicated that they did not have adequate time during the pilot process to do this. Some teams had a difficult time in understanding how reference values were translated into the analytical program and this made the process of developing reference values very confusing.

The Challenge of Setting Reference Values

"Developing the [reference values] for the model was probably the most challenging aspect of the whole project. This is because it is in the development of [reference values] that we had to directly address the actual meaning of sustainability and explicitly relate it to the real world phenomena our data purports to measure. Identifying elements which should be considered in the determination of sustainability is one thing, actually measuring these items, transforming the measures into a metric which is meaningful for sustainability and then mapping this transformation onto a set of [reference values] is quite another."

(Tongass National Forest Team)

In spite of the differences in approaches, there were a number of common findings:

- Identifying reference values was the most difficult (cognitively) portion of the process and could often be quite subjective.
- Identifying reference values for social and economic systems appears to be much more problematic, perhaps because of the lack of available information and our inherent understanding of the range of possible outcomes and states,; or alternatively, it could be that the measure is simply scaled incorrectly so that the indicator and reference value do not connect.
- Reference value development is fundamentally a values-based process. Even when reference values are standards based on legislation or science, they are still values-based. Often, however, these types of standards are perceived as more objective.
- "Developing [reference values] was extremely useful to understanding sustainability because it challenged underlying assumptions about complexity of systems and integration across sets with specificity" (Blue Mountains Team).
- Despite challenges, it was worth trying to come up with reference values because this is where the really tough questions emerge.

Based on their experiences, LUCID participants made the following recommendations to improve the process of establishing reference values. Specific suggestions on reference value source and construction approaches for each measure are included in the LUCID Resource Database (Appendix 9).

Clarify

Spend time on understanding the rationale or theory for establishing a reference value. The questions to ask are: What if the value for that indicator goes up? What if it goes down? Does the rate of change matter; and if so, over what time period or from what base position? Do you need to know anything else to understand what the indicator means? Will a change in another indicator affect this one? Defining the reference value focused on the same question as were faced in understanding the systems framework, "What are the important parts of these systems, what parts are we interested in measuring and monitoring, what parts are integral to sustained system functioning, and what terms or measurement units to use in the development of the standard. In standard-setting we focused on what questions we wanted to ask and often rephrased the question" (Ottawa National Forest Team).

Document Assumptions

Thoroughly document the information, perspectives, and assumptions used to develop the reference value. In the large part forest teams in the pilot process did not document adequately, but they recognized it as a critical step. For example, when setting a reference value for a set of economic indicators are you taking a short-term perspective or a long-term perspective? Is the reference value set on intra- or inter-generational needs, or do you need to set two different reference values and test against both?

Start Early

Forest teams found merit in beginning first with an understanding of the systems frameworks and then in the initial identification of indicators based on system structures and functions;, however, they felt that the process of establishing reference values should be conducted simultaneously with the development of measures. Discussing what a reference value would mean and would tell helped define the kind of information and the associated precision, time period, and spatial variation of the information that would be needed.

Discuss Interrelationships

There were a variety of different approaches to examining the relationships between the reference values. One approach was to set the initial reference value based on the need or perspective from within that particular system component. For example, in discussing reference values for deer population numbers on Allegheny National Forest, if the context was recreation (hunter) satisfaction the initial reference value would be something very different than if the reference value was being established for a measure of deer population effects associated with black cherry regeneration success. One approach to discuss and reconcile reference values was to initially set the reference values independently and then reconcile them. However, it is important to be clear and document whether establishing the reference value was based on one or all sets of considerations.

Be Specific

Going through the process of establishing reference values forced the development of more specific measures and reference values.

Standards Aren't Automatically the Best Reference Values

Legal or regulatory standards are usually established because we don't have enough science to establish reference points that vary based on the system structure-process relationships. Legal or regulatory rules are safety nets set in place until we know more about how the system operates. Often, legal or regulatory standards such as human health water quality standards seem more objective and legitimate, but they may not provide the best fit with the indicator under consideration. The assumptions behind standards should be questioned as closely as behind all other reference values. In a case where a standard has the force of law, one approach might be to compare the indicator against a second reference value and then look at the difference between the two and the assumptions behind each.

Expert Judgment Can Be Very Useful in Establishing Reference Values

Although almost all forest teams looked for additional, factual information to help develop reference values and often felt uneasy about relying on expert judgment in the development of reference values, almost all LUCID participants found it exceptionally useful. Since reference values are not absolute but merely an initial signal to compare a data value against and to start discussion, expert judgment, with thoroughly documented assumptions, is often a very useful way to establish the reference value.

Reconcile Reference Values

After reference values have been initially established in an independent way, they should be refined by looking for conflict. Particularly if the same data element (e.g., road density) is used in several places within the C&I hierarchy (e.g., as a data element to inform an indicator of accessibility and as a data element to inform a fragmentation indicator), there is a definite need to reconcile conflicting use of the same reference values. An approach that many have found useful in this situation is to examine the reference values for each instance of the data element simultaneously and discuss whether the reference values could be changed so that they overlapped and then what the management implications of such a modification would be.

Reference Values and Integration

Through the process of setting reference values for measures and reconciling differences between conflicting measures/reference values, the interactions and tradeoffs between systems interactions become much more clear. The process of setting reference values is a process of determining what the desired state of that system structure or function is. Even if reference values are set one measure at a time, identifying a benchmark to compare a data value to is a means of looking at system interactions. For example, establishing a reference value for desirable deer population numbers, even if done just for ecological reasons, is about interactions between kinds of ecological systems. Considerations include not just the population viability of the deer species but also the integrity of animal and plant communities and regeneration of forest types or specific seral stages. When the reference value discussion expands either within the monitoring program or within the decision-making process (e.g., in forest planning), the ecological system is integrated with socio-economic systems based on reconciling desirable deer population numbers with reference values for

Using Reference Values to Focus on What's Important

"An example from the ecological framework would be the Palmer Drought Index. By having 50 years of data to look at, we dug into the data to come up with a rational [reference value]. This actually makes the data value have more meaning and shows what can be done with trend data over time. In this case we decided to use 5-year periods and count the mean number of months in the growing season recording an incipient drought level to set the 0 level. The [upper value] was set at the wettest number in a 5-year period and the [lower value] at 25 percent below the driest number. So our 5-year data value of 12 showed us we were well below the mean of 7.33. You could take data values and do analysis to interpret them, but the [reference value] setting in this case applies the interpretation we were looking for."

(Allegheny National Forest Team)

recreation, opportunities for solitude, and the economic generation of tourism (hunter) income. Consequently, integration within and between systems is a further means to pursue the integration and calibration of desired conditions between systems.

Interdisciplinary and Collaborative

All reference values need to be established or reviewed and modified within an interdisciplinary context. Besides management input in the development of reference values, an expert review panel may be helpful in this phase. Although the specific numeric values of a reference value may or may not be discussed in a collaborative setting (this may be too specific for some audiences), the assumptions and theory behind the development of the reference values must be discussed broadly.

Conflict Will Center Around Reference Values

A systems-based approach similar to the LUCID Project may help collaborators agreement more easily on the best suite of C&I to monitor, but there will still be conflict. For example, "[t]he timber output necessary to sustain a local economy that is dependant for jobs on the local mill may conflict with the timber retention necessary to maintain habitat for a certain species" (Blue Mountains Team). A careful process of developing and documenting the basis for reference value development will assist in communicating more clearly but the reality is that determining the reference values is ultimately about making tradeoffs between often competing outcomes. Many forest teams commented on the desirability of comparing a common set of C&I against a variety of different reference values based on differing scenarios or perspectives (see Chapter 14). Although this would not reconcile the conflict; it would result in participants talking about and comparing against the same things. As Hannah notes, it can be "much more difficult to achieve consensus over targets than to identify the sustainability indicators themselves" (*In* Maclaren et al. 1996).

Discuss Regardless

Some LUCID participants felt that if they went through the process of discussing and trying to identify all of the above issues and factors, even if ultimately they were unable to set a reference value with any confidence, the result would nevertheless be worthwhile. The value in large part was in having the theoretical and practical discussions about the why and what they were including in the suite of C&I and what it would tell them if they knew the answer.

Suggestions for Developing Reference Values

LUCID participants indicated that discussing the rationale for establishing a reference value for an indicator was of primary importance. During the LUCID Project, forests teams took a variety of different approaches and commented in their evaluations on the strengths and weaknesses of the approaches and issues.

When Should Reference Values Be Developed or Changed?

Several forest teams found that developing reference values was an iterative and unending process. While a reference value may have been decided *a priori*, the forest teams often found themselves looking back to see if the reference value should be adjusted once data were valued and compared. From one perspective this iterative process seemed in keeping with an adaptive process and in particularly where the establishing of the reference value was highly arbitrary. However, LUCID participants also noted that they

No Pain—No Gain

"The process of setting [reference values] from the top down (within the C&I framework) encouraged the adaptation of measures focused on outcomes or function rather than the components that go into those measured outcomes or indices. Forest planning monitoring often gets high-centered on measuring the input components (widgets) of a phenomenon rather than the outcome index (and its link to the ultimate goal, measuring sustainability) and this is very cumbersome, costly, complex and evades the primary point of the monitoring. Setting [reference values] is a valuable exercise even though it can be very painful. But the reason it is painful is the reason that we ought to be doing it. Setting [reference values] brings up important questions and forces documentation of assumptions, exposing hidden agendas in some cases, capturing expert opinion in others. The proper (integrated) process of setting [reference values] has the potential to force collaboration as people will at some point have to hit upon a way to communicate and even possibly agree with one another in order to get through the process."

(Modoc Forest Team)

were concerned that this kind of after-the-fact adjustment made it look like they were "fixing" the reference value in order to obtain a better assessment hence the importance of keeping good records of the decision process.

A Risk Adverse Basis for Establishing Reference Values

One possible strategy for setting reference values was to use the reference value function from a precautionary principle perspective. In this scenario reference values would be set quite conservatively to provide an early warning of potential change. "Many [reference values] are risk-oriented because of uncertainty in what the [reference value] should be and the desire to not want to drop below a certain value (though that may not be the actual threshold value). Part of our strategy for developing [reference values] is the risk of making large mistakes" (Ottawa National Forest Team).

Reference Values of Short-Term and Long-Term Outcomes

Several forest teams noted that reference values cover near-term conditions as well as long-term conditions. In some cases it may be useful to set both types of reference values for each measure and examine the differences between them. Other forest teams found that they were able to include both short-term and long-term perspectives within the range of acceptable values included in the reference value.

Basic Conditions or Demands

The debate on the relationship between sustainability and desirability has been discussed in other places in the report. The Ottawa Forest Team, however, noted that they constructed their reference values largely on the ability of the Ottawa National Forest to supply the feature or process of interest and not on meeting any particular level of demand.

Using Reference Values from Existing Forest Guidance

Several forest teams explored the relationship between reference values for sustainability monitoring and those reference values contained within forest plans. Although there is similarity, forest teams reported that the reference values for sustainability monitoring varied considerably. At a forest level a careful review of the two sets of reference values may provide explicit links between monitoring and implementation;

On What Basis Are Reference Values Constructed?

"The large fluctuations over time of most social and economic data quickly became apparent and resulted in a variety of approaches to standards. Choosing two points for comparison was often not useful or instructive. In these cases the best approach for standards seemed to be to use a historic range of data for high and low standard values. In many other cases an increase of one thing could lead to a decrease in another, and choices for standards would inherently be value driven. A static state, or preservation of the highest level, isn't necessarily beneficial, either. In many situations the forest plan year was used as a reference for setting standards. In these cases we determined that the difficulty for the community was adapting to change, so we used a somewhat arbitrary level of + or – 20 percent to indicate an abrupt level of change... Economics is a world of tradeoffs and substitutions. In this sense, small is not important. Magnitude of change and adjustment to it are important. In summary, the lesson learned was that sustainability equals balance and constant adaptation to change in order to rebalance."

(Allegheny National Forest Team)

however, as they are based on different assumptions and timelines care should be taken in adjusting either. For example, Land Management Plan reference values often pertain to administrative activities that are prescriptive in nature and often a one-size-fits-all method of setting reference values for performance. "When this happens, generally standards and guides are set tightly sometimes with a strict, absolute requirement without a range of variability in environmental circumstances and conditions.... This leads to a high degree of failure, or [means that the forest needs] to be constantly amending standards and guides to allow for variation from the norm" (Modoc National Forest Team).

Similarly, many regulatory standards are not really sustainability reference values because they are not adapted to local conditions and the sustainability values associated with the forest.

Fuzzy Logic and Reference Values

Reference values could be set as either discrete (absolute or a range) or fuzzy values. Fuzzy reference values refer to the use of fuzzy mathematics (fuzzy logic) to assess a data point against a distribution of numbers that represent a range from –1 to +1. These values are often described as achievement. The values associated with the range between 100 percent achievement and 100 percent non-achievement can be evenly distributed or they can be stepped or sloped in any manner desirable. Setting fuzzy reference values meant that the user had to determine the points of 100 percent positive and negative and the shape of the curve between those points, including any intermediary values. Sensitivity analysis can be used to determine if the reference value was critical or less critical to the determination.

Standards and Guidelines and Sustainability Reference Values

"Standards and Guidelines (S&G's) in Forest Service management are intended to assure some level of multiple uses or to achieve legally required minimums during management activities. Neither of these concepts has anything to do with the standards that the Tongass LUCID Team set with respect to level of sustainability. Quite simply, traditional S&G's relate to management direction, while LUCID standards relate data elements and data calculations to some perceived levels of sustainability."

(Tongass National Forest Team)

The LUCID core team was interested in exploring the use of reference values based on fuzzy logic because we felt that absent situations where the reference value was discrete (e.g., yes or no) or in the few situations where there were known thresholds (e.g., a minimum viable population size for an endangered species based on genetic bottlenecking models) any given indicator did not have an absolute target that must be achieved. We felt an approach that suggested a reference value would have higher information value if it was able to characterize how closely an indicator came to the reference value not simply a pass/fail value.

Forest teams were encouraged to evaluate the utility of a fuzzy logic approach to setting reference values, and analytical tools (Chapter 13) were provided that could use reference values that were either fuzzy or discrete in nature. Although there was a stiff learning curve involved in understanding how fuzzy reference values worked analytically, all forest teams found the approach very useful. Ultimately, they used a combination of approaches for establishing reference values from discrete (absolute and a range) to fuzzy although the large majority of reference values were fuzzy in nature. Teams noted that they found the fuzzy logic approach was useful because it very flexible and in particular "helped in the construction of [reference values] where data were incomplete or the relationships within the [measure] were complex and difficult to capture with a [reference value] expressed as an absolute number or value" (Tongass National Forest Team).

Fuzzy reference values could help demonstrate where progress was being made, even if it wasn't fully achieving its target. Although "[c]onceptually, this was a way to simplify the approach to determining [reference values] for sustainability… in practice determining the higher or lower ends of the spectrum was the most troubling" (Blue Mountains Team). For example the Blue Mountain Team found that with respect to land ownership the data showed that a reference value set to prefer a higher proportion of private land ownership would provide higher economic stability however State and Federal laws protecting ecological values were less protective on private land. Teams noted that sensitivity testing was required to help establish the reference value.

The addition of reference values set using fuzzy logic was a further way to overcome potential concerns that reference values may imply a discrete or absolute determination of sustainability.

The Temporal Dimension to Reference Values

The temporal dimension to sustainability, both inter- and intragenerational, was a key concern to LUCID participants. Reference values were useful tools in helping consider temporal issues. Reference values based on reference conditions (e.g., Historic Range of Variability) required a precise specification of the time period that was being referred to. Beyond this approach, however, many teams incorporated the temporal dimension into the full range of reference values. In some situations the reference value was established based on an averaged set of numbers (e.g., 5- to 10-year averages) to avoid a high signal-to-noise ratio from highly variable data. Others found that with respect to indicators that are always under flux and where the direction of change might be acceptable regardless of the direction of the change, assessing a percent change over time either from a fixed or floating base helped identify the key aspect. In other situations forest teams suggested that they might set one reference value based on short-term outcomes and then a second reference value based on long-term outcomes and compare the two.

Finding time series data to help establish these reference values and to serve as the database was more difficult. Established inventory database systems (e.g., FIA/FHM) contained some good historical data as did forest accounting systems such as INFRA. The challenges tended to be associated with differences in the scales, units, and conversions that often made it difficult to use.

Spatial Variability and Reference Values

Reference values were not only specific to a given forest but they were often variable within a forest. Reference values for disturbance frequencies varied based on the ecological land type or watershed of focus. Depending on how a forest team's data were structured, they could set a different reference value for each polygon to accommodate these differences. Further, some teams constructed reference values on a percentage area basis (e.g., percent of watershed impaired).

Reference values need not always be spatially variable. In some cases there may be a desire to have a consistent reference value (for example, an employment rate) across all areas of the forest, but in other situations this may not be possible. Some reference values will work particularly well across ownership or jurisdictional boundaries (e.g., lotic/lentic proper functioning condition of streams since the variability of the landscape is built into the application of the protocol) while in other circumstances the change in ownership and consequently management objectives will necessitate a change in the reference value. By and large, the forest teams anticipated that it was within the ecological systems that there would more likely be spatial variability in reference values given the high degree of human mobility. It may be more likely for there to be consistent reference values between common management units or ecological land units; consequently, coordination and sharing of information in the development of reference values both within and between forests is suggested.

Sources and Availability of Reference Values

LUCID forest teams used a wide variety of sources to help establish reference values from scientific information to professional judgment. Many participants noted that within the socioeconomic sphere in particular, professional judgment was the dominant foundation for establishing reference values since there was often little information available.

Many forests teams found the forest plan and amendments provided a useful source of reference values, and some teams were able to consult other regional documents. For example, the Blue Mountains Team used the Oregon State benchmarks documents as references for socio-economic indicators and felt that using these might also help synchronize the forest's reference values with State and county-level planning efforts. Other commonly used sources included regional direction requirements, region-wide environmental impact statements, EPA, and historic/reference data collections or studies (e.g., ICBEMP). Inventory data also provide an excellent source of information for constructing reference values.

In the absence of other information, some teams had real challenges in developing reference values. The Allegheny Team found that in the case of socioeconomic reference values as a temporary measure they often took the current data value for the indicator and then set a degree of tolerance around it. These, they felt, became more of a measure of change from the status quo than an optimally designed sustainability reference value. In a somewhat similar scenario, the Blue Mountains Team adopted a default approach when they had nothing else to work with based on their forest plan monitoring strategy that looked at a percent change (e.g., + or – 15 percent from year to year) over time as a way of signaling whether there might be an issue. Based on these and similar challenges, LUCID participants suggested that it might be useful to clarify the certainty or comfort level with the reference value and adjust or weight it accordingly.

Consistency and Flexibility

Concerns about consistency and flexibility are as prevalent in the discussion of reference values as they are in the design of an optimal set of C&I. Standardization does allow for a consistent look at the same suite of things across a number of areas (e.g., national forests) and it also allows people to communicate in common, comparable terms. Often, however, a standardized or consistent approach can lead to attempts to directly compare between scenarios without regard for changes in context. This is particularly the case with respect to establishing reference values. Some reference values may indeed be standardized (particularly legal and regulatory standards); but most will need to be flexibly developed both within and between forests so that ecological, social, and economic variation, local interests, and specific management issues can be assessed.

However, while it may not be appropriate for the actual values within the reference value to be standardized it may be useful to use consistent means of establishing reference values in specific cases. Each of the LUCID forest teams used different approaches to setting reference values even when the measure was common. For an indicator associated with income levels one forest may have developed the reference value based on a comparison to average regional incomes while another may have developed a reference value based on a community assessment of living wages. As experience in establishing reference values increases, there may be a desire to use a consistent method for establishing the reference value.

A second area where a consistent or standardized approach may be useful is in the interpretation of the terms and assumptions associated with reference values. Forest teams found that even within their teams they often had different interpretations of how they understand the benchmarked values in fuzzy standards.

Remaining Challenges

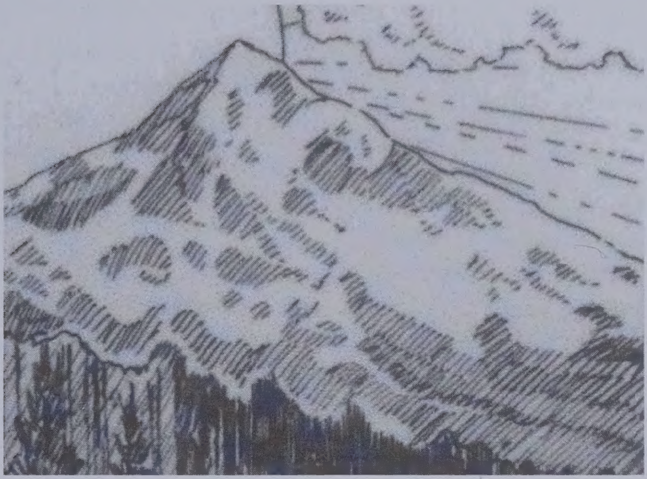
As one LUCID participant mentioned, setting a reference value is like trying to identify a moving target. Not only may we be unable to establish reference values for all indicators at this point in time, but they all will need to be revisited and confirmed. The experience of setting reference can be challenging and imprecise, but LUCID participants recommended it as a critical part of the process of monitoring for sustainability. Many other national and subregional C&I initiatives are beginning to engage discussions of the values and merits of reference values, and in time there may be new insights and experiences on how and when to set reference values.

CHAPTER HIGHLIGHTS

- Reference values come in a wide variety of names (benchmark, standard, trend, threshold, desired future condition, norm), but all refer to a comparison to which an indicator can be examined or gauged.
- Reference values give us a point of reference to help interpret what we know about an indicator; to force discussion about what the measurement of an indicator is telling us; to help us assess whether we are moving in the desired direction and at the right pace; and to help identify what other things interact with or are affected by that indicator.
- Even though developing reference values was extremely challenging LUCID forest teams found that setting reference values was an extremely valuable and necessary step that helped clarify what was being measured, the spatial and temporal dimensions and assumptions of sustainability.
- Reference values are not static in nature but may change or shift over time with improved knowledge, changing conditions, and shifting values and will need to be revisited and confirmed in some broader forum. Many will also vary not only between forests but within different areas on a forest.
- Although discrete reference values were useful in certain situations LUCID participants found that setting reference values to reflect graduated degrees of attainment (fuzzy reference values) were the most useful in the context of sustainability.
- Teams were not able to identify reference values for every indicator at this time and further work and research are needed to help identify methods to construct reference values and to acquire the data necessary to do so.

CHAPTER 11.

A CORE SUITE OF FMU-SCALE CRITERIA AND INDICATORS



BACKGROUND 175

A brief overview of the objectives and questions associated with developing a suite of FMU-scale Criteria and Indicators.

THE PROCESS 175

Summarizes the steps involved in identifying a core suite of FMU- scale Criteria and Indicators from the results of the six forest tests.

THE LUCID EXPERIENCE: THE FINAL SUITE OF FMU-SCALE CRITERIA AND INDICATORS 176

Highlights the final suite of principles, criteria, indicators, and measures and provides an overview of the Resource Database that provides detailed information on each of the elements.

> "Local level indicators (LLI), which are developed to suit local and regional conditions, provide the framework for monitoring on-the-ground changes and assessing their influence on the many components of sustainable forest management".
> (Canadian Model Forest Network 2002)

BACKGROUND

The foremost objective of the LUCID Project was to test, develop, modify, and evaluate criteria and indicators (C&I) to assess the sustainability of ecological, economic, and social systems at the forest management unit (FMU) scale. The questions explored by the LUCID participants included:

- To what extent would there be commonality in C&I across the range of LUCID sites and a range of ecological and socioeconomic conditions?
- Could a core set of C&I be developed that would work across these settings?
- What principles and criteria would be more likely to be common and what would be variable?
- How did the desire for consistency and the needs for flexibility factor into the development of a core suite of C&I?

THE PROCESS

Development of a Core Suite of FMU-Scale Criteria and Indicators

The development of the core suite of C&I occurred in an iterative fashion. Chapter 4 provides an overview of the development and testing process. Specific detail about each step in the C&I hierarchy is provided in the more detailed sets of Chapters from 6 through 10.

As forest teams concluded their work, an initial database of the names, definitions, and details of the forest teams' PCIM was built to help evaluate the similarities and differences between each forest's set of C&I (and the original set of C&I). A multistage review was undertaken to identify a revised set of core criteria and indicators and to identify common threads across all forests. The purpose was to determine if there was a core suite of C&I that might be generally applicable across the national forests system to assist in monitoring for sustainability at the FMU scale. The intent was not to select a criterion or indicator just because it was used by the majority of forest teams but rather to work from their experiences.

Following review and revision to the systems frameworks, the core team compiled a database of similar elements (e.g., all criteria and then indicators and measures relating to the economic concept of capita'). In an interdisciplinary discussion, the connection of the element to the systems framework was revisited and the core team sought to identify the best element(s) within that area. We developed a series of decision rules or protocols to help in selecting the best element including:

- Constant reference to the systems framework (albeit revised as necessary);
- Selection of elements (e.g., indicators) not necessarily because they were used by the most pilots (e.g., four out of six pilots used a given indicator) but rather because that element was the best one within a systems context that provided the highest quality data and met the evaluation criteria;
- Giving advantage to an element that included the highest information value (e.g., an index) rather than an element or series of elements that required additional processing or interpretation;
- Looking for those areas of innovation with a forest team's work and trying to include them, where they met the selection criteria, in the final suite of C&I;

- When forest teams expressed uncertainty about a specific element (e.g., productivity or nutrient cycling), the core team revisited other suites of C&I and the literature to try and identify better options for elements; and
- Double-checking the wording against the hierarchy decision rules as well as for applicability at the local scale and to a range of forested and nonforested environments.

This revised list was then subject to a series of group and individual reviews. As was the experience of the forest teams, the process was iterative in nature. A revision to a measure often led to the need to revisit and revise indicators.

Decisions and Assumptions in the Development of the Final Criteria and Indicators

The development of the final C&I was based on a series of decisions and assumptions.

Hierarchical Levels

Six hierarchical levels were used to organize the C&I including principles, criteria, indicators, measures, data elements, and reference values. In situations where the measure relied on only one piece of information data elements were not needed.

Wording Rules

To clearly focus on what was being monitored and to facilitate consistency particularly at the higher levels of the C&I hierarchy, we tried to follow a set of wording rules for each of the hierarchical levels. The tradeoff for consistency is that the wording tends to be quite generic; however, additional information that can be used to help clarify the intent of the item including specific definitions is provided in the LUCID Resource Database (Appendix 9).

Spatial Scale

Considerations of spatial scale became central to the work of the forest teams. Identifying the spatial scale(s) for indicator monitoring was key to making the results useful for forest management. Choices regarding the spatial scales of interest and the study units (e.g., watersheds, vegetation communities, counties, and communities) were based on systems properties, the sustainability stories that were important to tell for that forest, the measurement methods, and the availability of data. In some cases forest teams found that they needed repeated measures for different spatial units (e.g., by watershed) where in others they had a common measure but separate data elements or reference values. The variability in the approach depended a great deal on the specific issue of study and how the database was constructed. As a result, the final suite of C&I does not specify or prescribe a specific or single spatial scale for each indicator although measure wording and explanations often provide an indication of the kinds of spatial units that may be used to organize the monitoring information.

A Common Numbering System

To track and identify principles, criteria, indicators, measures, and data elements, a unique and common numbering system was developed. The hierarchical relationships can be traced through the numbering system such that indicator 1.1.1 is associated with criterion 1.1 and principle 1. Between components (e.g., principle 1 compared to principle 2) there is no importance to the ordering system. Principle 1 is principle 1 merely because it started that way at the beginning. Similarly, there is no implied order or importance to elements within a component (e.g., indicators within a criterion).

A Work in Progress

At each stage in the development process, the C&I were revised, adapted, and refined. The C&I were developed and tested under a broad range of conditions, and they remain a work in progress. With subsequent reviews and the experience gained from repeated monitoring, we would expect and hope that the suite is revised. This is particularly the case at the lower levels of the hierarchies (measures – reference values) where there had been little historical work to build from.

The LUCID Experience: The Final Suite of FMU-Scale Criteria and Indicators

One of the primary objectives of the LUCID Project was to try and identify a common core set of C&I that could be used at the FMU-level across the national forests system. Consistency in items was desirable if they were evaluated as useful and applicable across the range of conditions.

Principles and Criteria

The experience of the LUCID forest teams showed that a common systems-based framework, defined by 3 principles and 16 criteria, could be used across the range of test sites to provide a common organizing foundation and language to discuss the sustainability of ecological, social and economic systems (see Figures 22 through 24).

Indicators

Framed within the principles and criteria is a common core set of 58 indicators that are *recommended* for consideration across all national forests. There are 21 indicators each for the social and ecological principles and 16 for the economic principle. By and large, these indicators appear to be generally applicable across the range of conditions and ownerships although in some specific cases (e.g., the economic indicator of "natural capital range") an indicator may not be appropriate in all settings. The set of common indicators included in the final suite is the minimum set judged necessary to address the criterion. Individual forests may wish to include additional indicators to address specific concerns or issues. Supplementary indicators can also be framed within a systems context thus making the relative relationship to the core suite understandable and interpretable.

Measures, Data Elements and Reference Values

From the measure level down there is much less consistency, and much more variability and flexibility are required. In part this is due to the recognition that there is still a great deal of room for improvement in the selection of measures and data elements. It is also a natural outgrowth of the fact that no two forests are exactly alike. Forest teams and LUCID forest supervisors highlighted the importance of flexibility in the monitoring system, in particular from the measure on down. Differences in ecological and socioeconomic conditions from forest-to-forest mean that at times different protocols are required to assess the same indicator. Similarly, a forest may need to focus on a specific aspect or element of an indicator that relates to a management issue or the concerns of stakeholders. Forests also often have access to very different technologies and expertise for monitoring and to data that can influence the choice of measures.

The core team identified three different kinds of measures including:

1) Recommended Measures.
2) Proxy Measures, and
3) Optional Measures.

Recommended measures include those found to be relatively consistent from forest to forest. Where possible, these are based on standard, recognized Forest Service protocols or ideas. Recommended measures should be evaluated for applicability to the forest along with compatibility with existing data. Recommended measures are signified by the letter "M" (Measure) followed by a unique number referring to the associated indicator, criterion and principle (see Figure 25).

Proxy measures are included as a substitute for the recommended measure. While the recommended measure is the preferred or more common measure, the proxy measure presents an alternative means of obtaining the information. In some cases two or more measures are included as the proxy to a recommended measure. A proxy measure may be the preferred measure, but its use is so limited that it was included as a proxy. Proxy measures have the same number as the recommended measure but are preceded by the letters "MO" (Measure Optional). Within representations of the conceptual model, proxy measures are attached by dashed lines and boxes on the right (or bottom side) of a "sequential or."

This "sequential or" indicates that the preferred measures is the left or top measure but where that information is not available the proxy substitute is the measure to the right/bottom (see Figure 25).

Optional measures include those that forests might consider adding to their list of measures based on the issues of interest and concern at the forest level. Not all of these measures would be equally applicable from forest to forest. Optional measures have their own unique number but are also preceded by the letters "MO." Within the conceptual model diagram optional measures have offset dotted lines and boxes (see Figure 25).

As with the indicators, individual forests may wish to include additional measures to address specific concerns or issues. In addition to the optional measures identified in the list, forests may find it useful to look for ideas within the C&I developed by the six LUCID forest teams.

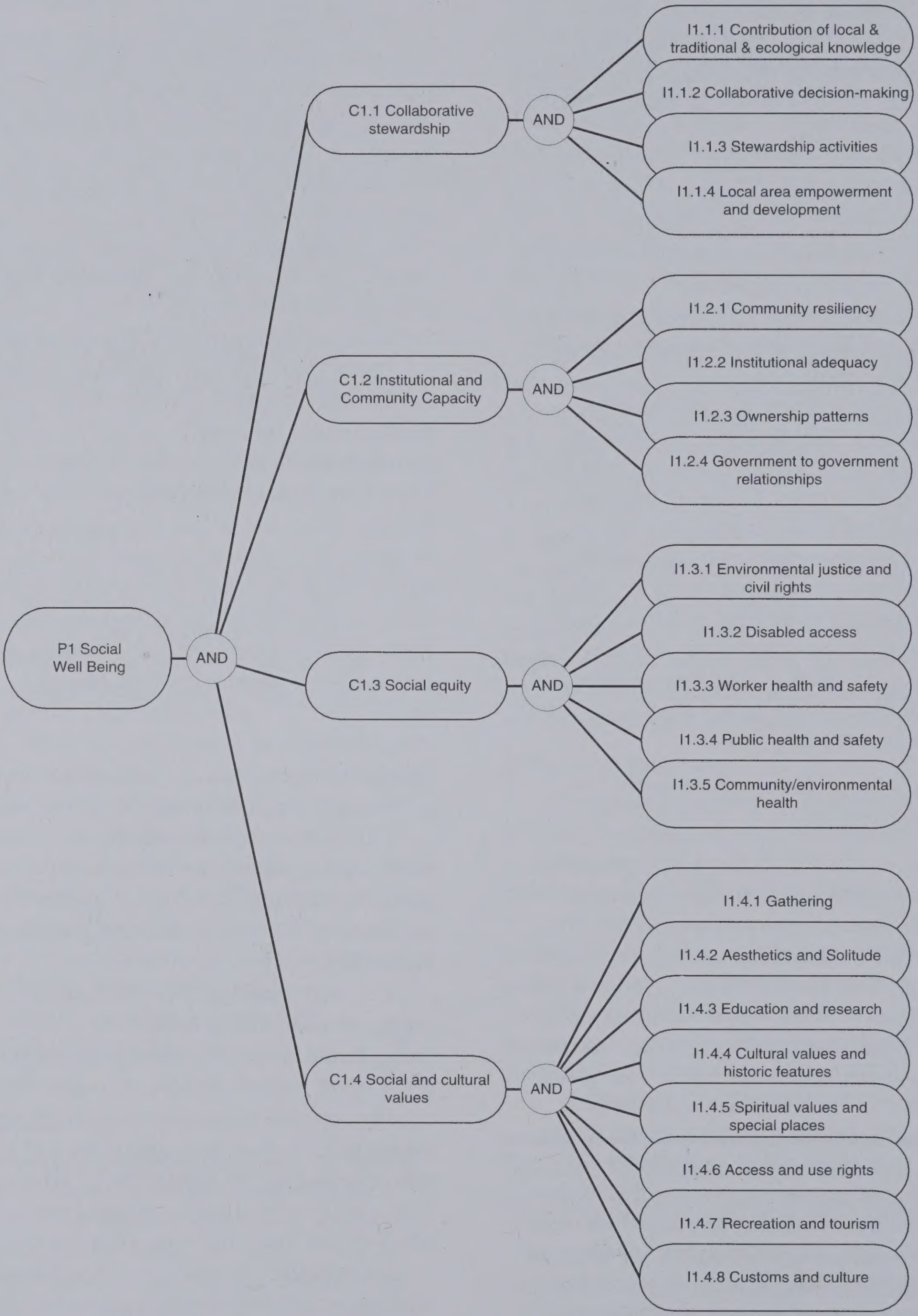

P1 Social Well Being
AND
C1.1 Collaborative stewardship
AND
I1.1.1 Contribution of local & traditional & ecological knowledge
I1.1.2 Collaborative decision-making
I1.1.3 Stewardship activities
I1.1.4 Local area empowerment and development
C1.2 Institutional and Community Capacity
AND
I1.2.1 Community resiliency
I1.2.2 Institutional adequacy
I1.2.3 Ownership patterns
I1.2.4 Government to government relationships
C1.3 Social equity
AND
I1.3.1 Environmental justice and civil rights
I1.3.2 Disabled access
I1.3.3 Worker health and safety
I1.3.4 Public health and safety
I1.3.5 Community/environmental health
C1.4 Social and cultural values
AND
I1.4.1 Gathering
I1.4.2 Aesthetics and Solitude
I1.4.3 Education and research
I1.4.4 Cultural values and historic features
I1.4.5 Spiritual values and special places
I1.4.6 Access and use rights
I1.4.7 Recreation and tourism
I1.4.8 Customs and culture

Figure 22. Social Criteria and Indicators

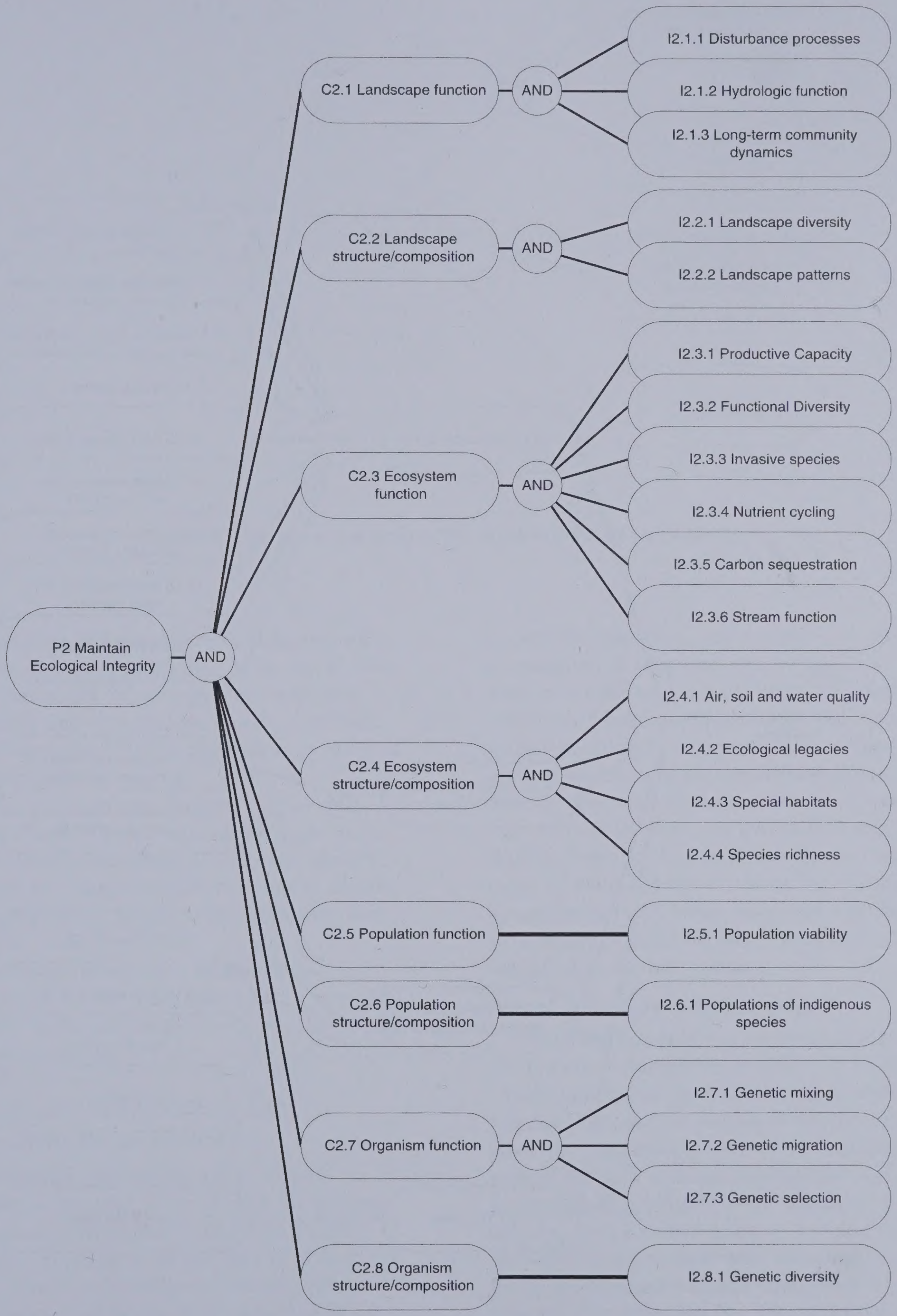

P2 Maintain Ecological Integrity
AND
C2.1 Landscape function
AND
I2.1.1 Disturbance processes
I2.1.2 Hydrologic function
I2.1.3 Long-term community dynamics
C2.2 Landscape structure/composition
AND
I2.2.1 Landscape diversity
I2.2.2 Landscape patterns
C2.3 Ecosystem function
AND
I2.3.1 Productive Capacity
I2.3.2 Functional Diversity
I2.3.3 Invasive species
I2.3.4 Nutrient cycling
I2.3.5 Carbon sequestration
I2.3.6 Stream function
C2.4 Ecosystem structure/composition
AND
I2.4.1 Air, soil and water quality
I2.4.2 Ecological legacies
I2.4.3 Special habitats
I2.4.4 Species richness
C2.5 Population function
I2.5.1 Population viability
C2.6 Population structure/composition
I2.6.1 Populations of indigenous species
C2.7 Organism function
AND
I2.7.1 Genetic mixing
I2.7.2 Genetic migration
I2.7.3 Genetic selection
C2.8 Organism structure/composition
I2.8.1 Genetic diversity

Figure 23. Ecological Criteria and Indicators

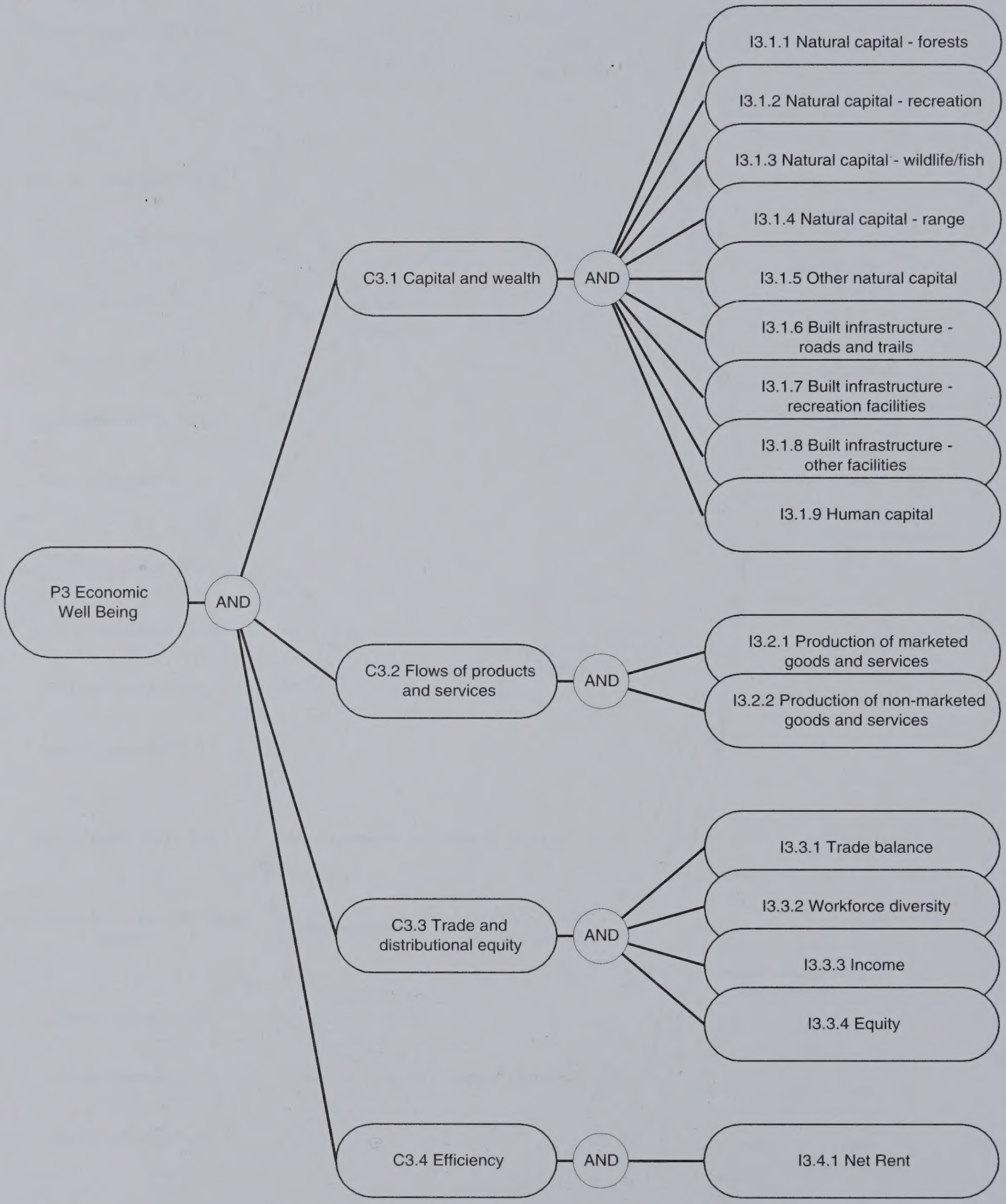

P3 Economic Well Being
AND
C3.1 Capital and wealth
AND
I3.1.1 Natural capital - forests
I3.1.2 Natural capital - recreation
I3.1.3 Natural capital - wildlife/fish
I3.1.4 Natural capital - range
I3.1.5 Other natural capital
I3.1.6 Built infrastructure - roads and trails
I3.1.7 Built infrastructure - recreation facilities
I3.1.8 Built infrastructure - other facilities
I3.1.9 Human capital
C3.2 Flows of products and services
AND
I3.2.1 Production of marketed goods and services
I3.2.2 Production of non-marketed goods and services
C3.3 Trade and distributional equity
AND
I3.3.1 Trade balance
I3.3.2 Workforce diversity
I3.3.3 Income
I3.3.4 Equity
C3.4 Efficiency
AND
I3.4.1 Net Rent

Figure 24. Economic Criteria and Indicators

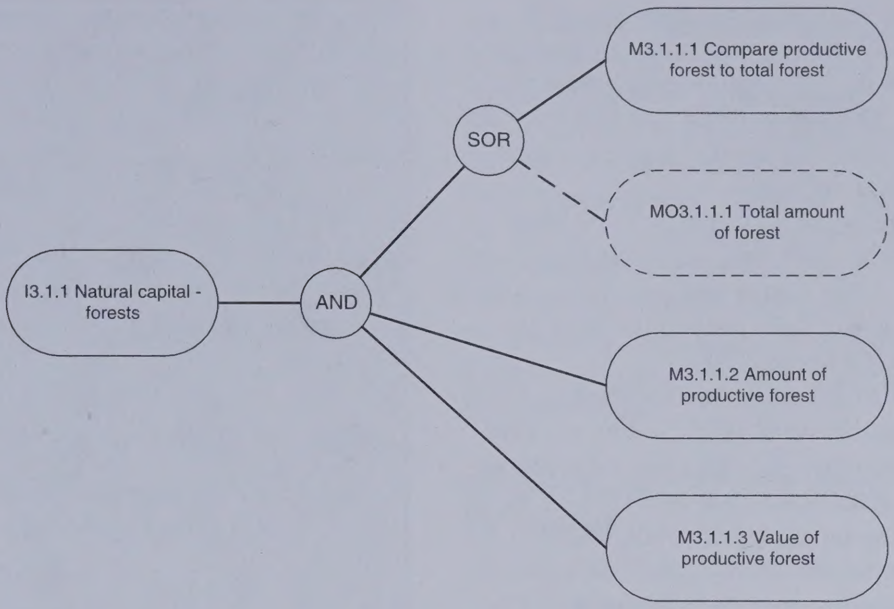

I3.1.1 Natural capital - forests
AND
SOR
M3.1.1.1 Compare productive forest to total forest
MO3.1.1.1 Total amount of forest
M3.1.1.2 Amount of productive forest
M3.1.1.3 Value of productive forest

Figure 25. Example of the Types of Measures Associated with Indicators

There are 119 recommended measures within the LUCID core set, including 36 social (13 with proxy measures), 38 ecological (11 with proxy measures), and 45 economic measures (18 with proxy measures). The list of measures is included in Appendix 10.

The data elements required to assess each measure have so much variance from site to site that we did not find it useful to try and identify a common list. Suggested data elements to support the recommended measures are included in the database.

Similarly, information on approaches and sources for reference values are included within the database in association with each measure.

Preliminary Relationships with Corporate Data Sources

Corporate data systems (e.g., Forest Inventory Analaysis, Forest Health Monitoring, and Natioinal Rresource Inofrmation System) provide a potential source of data to be used for FMU-scale sustainability monitoring. Some preliminary evaluations of the potential fit of these corporate data sources to C&I suites has been conducted typically for larger scale monitoring initiatives. For example a 2001 examination of proposed metrics and data sources for the base sets of forest sustainability indicators for the Northeastern United States identified potential data sources including Federal government sources, USDA Forest Service, Resource Planning Analysis Assessment, Forest Inventory Analysis, USDA Fish and Wildlife Services, United States Census, and a range of State and other sources for metrics associated with 16 broad indicators. Particular data elements and scale issues were not identified in this comparison.

Forest Inventory Analysis (FIA)

The 1998 Forest Inventory Strategic Plan (USDA Forest Service Forest Inventory Analysis 1998) examined the applicability of FIA data to the Montreal Process C&I and noted that the inventory program would address some of the indicators at a scale of the State or larger. Twelve indicators, predominantly ecological, were identified as being reported on as a normal course of business and an additional nine indicators were identified that might be addressed with additional effort. The Strategic Plan noted that FIA data may be available to support an additional seventeen indicators although it would not be the primary source.

A recently released paper reporting on the results of a field test examining the applicability of FIA data to the Montreal Process indicators (Miles 2002). The author found that FIA data was available at a statewide level to support at least eleven biological indicators.

In a general sense, FIA suggests that basic forest mensuration plot data and forest cover data is good down to the county level on average and non-tree data is generally good to the State or regional level (Gillespie 2001).

A number of the components of the FIA Phase 3 program that originated from the Forest Health Monitoring plots provide additional information. To an even greater extent than the Phase 2 FIA plots, the coarse sampling scale will, however, constitute a barrier to the direct use of these data (unless an intensive sampling program is underway). The associated protocols developed for these measures may, however, be of specific value at the forest level. As these protocols are well developed, forests may be able to directly implement them on a scale that makes sense for FMU-level sustainability monitoring.

The FIA program also provides data and reports that provide useful context for the State and Regional setting within which the national forests exists (e.g., United States Forest Facts and Historical Trends or the Resource Planning Act Assessment). Although data from these reports may not be directly applicable at the forest level, this information could be used in the analysis and reporting phases to provide a regional context for the forest.

Finally, the FIA program and protocols have been developed within a clear quality assurance—quality control (QAQC) environment. Regardless of the applicability of FIA data to FMU-level sustainability monitoring, developing a comprehensive QAQC program modeled perhaps on the FIA program would result in a much improved and more reliable suite of data.

Where there was overlap between a measure within the LUCID final suite of C&I and the FIA Phase 3 measures, the link has been provided in the description of measurement methods.

NRIS

Although individual forest teams were not able to fully use the NRIS system as a potential data source because it is still under development, we conducted a preliminary comparison between the recommended suite of FMU C&I with the NRIS databases. Where data sources within the NRIS and related corporate data systems could be identified with potential application for the LUCID indicators, the data sources were noted in the resource database. Much of the NRIS system remains a work in progress, so future plans for protocols and comments on data availability are noted as necessary. Although this was only a preliminary assessment with a great deal more follow-up work required, the addition of this information does provide a potential source of data for forests undertaking FMU-level sustainability monitoring programs.

IMIT Protocols

The Inventory and Monitoring Issues Team (IMIT) has been charged with identifying and developing a series of monitoring protocols at a range of spatial scales as part of the directives component of the Planning Rule and these will serve as a means of conveying data into the NRIS data management system. IMIT protocol teams are working in a variety of areas organized typically by functional area (e.g., soils, terrestrial, wilderness). The extent of integration and spatial scales of application vary by team. Because the teams are currently focusing effort on formalizing *de facto* protocol standards they have not applied an overall formal systems framework. As these protocols are completed and new protocols are initiated a systems framework such as used for LUCID should be considered. As these protocols

New Tools to Help Determine the Accuracy of Plot Data for Forest-Scale Monitoring

Plot-based monitoring programs such as the Forest Inventory Analysis and Forest Health Monitoring initiatives can potentially supply data for a number of measures within the LUCID suite of C&I if the sampling intensity is sufficient enough to be reliable.

ECOVEBA (*Exact Coeffiecient of Variation Estimation Bootstrap Applet*) uses plot data (e.g., FIA, FHM) to calculate the coefficient of variation of the means of forest attributes (e.g., basal area, cubic foot volume), for a specified forest stratum, over a range of sampling intensities. This statistical estimate is useful to determine the sample size necessary to achieve a desired accuracy are more fully developed and enter the testing phase in 2002 there will be an opportunity to examine the applicability of the protocols as possible measures for LUCID indicators.

Although work remains to be done in investigating and pursuing the possible relationships presented within corporate data sets, a preliminary comparison of the final suite of C&I against some of these data sets was completed for this project. Of the 61 ecological measures examined, at least one potential corporate data source was noted for twenty percent and data could be derived from corporate data sources for a further twenty percent. Fifteen percent were possibly available from USFS or other government sources. Scale issues were not clearly resolved during this preliminary comparison, however.

Use of Remotely Sensed Technologies

The resolution and digital manipulation of data from remotely sensed technologies such as aerial photography and satellite imagery are increasingly providing cost-effective methods of collecting and analyzing meaningful information at a range of spatial scales (Peterson et al. 1999).

An examination of potential application of space imagery techniques to the Canadian Council of Forest Ministers suite of C&I indicated that there was a substantial role for remotely sensed technologies to 16 indicators and a partial role on a further nine indicators (Goodenough et al. 1998). There is no doubt that the larger the spatial scale the more likely that remotely sensed technologies will have utility in providing monitoring data.

To assist in identifying the potential for using remote-sensing technologies in the development of cost-effective measurement protocols, the Remote Sensing Application Center (RSAC) conducted a preliminary review of the ecological indicators and measures to examine the potential application of remotely sensed technologies to FMU-level sustainability monitoring. Approximately 40 percent of measures were rated as medium to high level potential for successful application of remotely sensed technologies and an additional 30 percent as low potential. The rest were rated with no or limited potential for application of remotely sensed technologies. This information is summarized in the LUCID C&I Resource Database (Appendix 9).

Based on this preliminary comparison and identification of needs, RSAC has begun a project titled "Development of Remote Sensing Technologies for Monitoring Ecosystem Structure and Function Indicators for FMU-Level Sustainability Assessments" in cooperation with the Inventory and Monitoring Institute and participating national forests (e.g., the Allegheny National Forest).

Supporting LUCID C&I Resource Database

Researchers involved in the CIFOR-NA test found that while there had been a great number of C&I initiatives and project, few had provided detailed documentation of the rationale for selecting the indicators and the associated methods. Although the categories for documentation were enhanced during the CIFOR-NA project, they were not built into a readily accessible and searchable and relational format. In response to these types of concerns, CIFOR constructed an electronic resource database and indicator modification form that served as the foundation for the LUCID effort. We based our work on examination of several other similar databases (CIFOR n.d., Environment Canada 2002).

The list of principles, criteria, indicators and measures (PCIM) names the elements; but additional information is needed to fully describe them. The LUCID C&I Resource Database (Appendix 9) provides descriptions, definitions and details of the C&I and was built from the initial work of CIFOR-NA and the experiences of the LUCID forest teams (see Appendix 10). The intent of this C&I resource database is to serve as a repository for information about each of the C&I elements in an easily searchable and accessible format. Data element and reference value information are included as a subset of the measures component.

This database is a work in progress and suggested changes or enhancements are discussed in Chapter 15.

CHAPTER HIGHLIGHTS

- The purpose was to determine if there was a core suite of C&I that might be generally applicable across the national forests system to assist in monitoring for sustainability at the FMU scale. Consistency in items was desirable if they were evaluated as useful and applicable across the range of conditions.
- A common systems-based framework, defined by three principles and sixteen criteria could be used across the range of test sites to provide a common organizing foundation and language to discuss the sustainability of ecological, social, and economic systems.
- Framed within the principles and criteria are a common core set of fifty-eight indicators that are *recommended* for consideration across all national forests. These indicators appear to be generally applicable across the range of conditions and ownerships. The set of common indicators included in the final suite is the minimum set judged necessary to address the criterion.
- From the measure level down there is much less consistency and much more variability and flexibility are required.
- The core team identified three different kinds of measures including:
    1. Recommended measures include measures found to be relatively consistent from forest to forest. Where possible these are based on standard, recognized Forest Service protocols or ideas. Recommended measures should be evaluated for applicability to the forest along with compatibility with existing data.
    2. Proxy measures are included as a substitute measure for the recommended measure. While the recommended measure is the preferred or more common measure the proxy measure presents an alternative means of obtaining the information.
    3. Optional measures include additional measures that forest's might consider supplementing their list of measures based on the issues of interest and concern at the forest level.
- Corporate data systems and remotely sensed technologies provide a potential source of data to be used for FMU-scale sustainability monitoring. Some preliminary overlaps have been identified but further work and comparison is needed.
- The LUCID C&I Resource Database available on CD provides descriptions, definitions and details of the principles, criteria, indicators and measures, and was built from the initial work of CIFOR-NA and the experiences of the LUCID forest teams. The intent of this C&I resource database is to serve as a repository for information about each of the C&I elements in an easily searchable and accessible format.

SECTION 4:

ANALYSIS AND SYNTHESIS

CHAPTER 12. ASSESSING SUSTAINABILITY: ANALYSIS AND SYNTHESIS

Examines critical questions facing approaches sustainability assessments and the relative value of an assessment versus a determination. Discusses the approaches to analysis and synthesis in the LUCID Project.

CHAPTER 13. ASSESSING SUSTAINABILITY: ANALYTICAL TOOLS AND ISSUES

Reviews a set of desired key features for analytical purposes and discusses the experience of the LUCID forest teams for each of those features. Summarizes the implications of using technical tools to assist in assessing sustainability and suggests areas for further development.

CHAPTER 12.
ASSESSING SUSTAINABILITY: ANALYSIS AND SYNTHESIS

BACKGROUND: ASSESSING SUSTAINABILITY 187

➠ *Examines the critical questions facing approaches to assessment, the differences between synthesis and analysis, and the relative value of an assessment versus a determination.*

THE LUCID EXPERIENCE WITH ANALYSIS AND SYNTHESIS 188

➠ *Discusses the role and value of conceptual models to guide indicator selection and to establish a framework for synthesis and reviews possible approaches both for individual indicator examination and assessment of the state of systems including spatial applications and the presentation of results.*

> "Conceptually, what seems to be required is a complete and comprehensive model for the entire world and every living and non-living system in it. If such a model existed, we might be able to predict with reasonable certainty where we are headed, foresee disasters and be guided to take action to avoid them. We would know which are the critical variables to watch for (e.g., the indicators). Unfortunately, no such model exists and one will likely not be built in the near future. The real question is whether there are practical and useful models somewhere in between these ideal and linear single-issue models."
> (Rutherford 1997)

BACKGROUND: ASSESSING SUSTAINABILITY

The purpose of establishing a sustainability-monitoring program is to help facilitate on-the-ground management by providing feedback on the state of systems and through engaging collaborators in a dialogue about sustainability. Ensuring that the resulting program is not just "monitoring for monitoring sake" (Grumbine 1994) involves the functions of synthesis, analysis, interpretation, and presentation in order that monitoring data are converted to useable knowledge as part of the broader adaptive management process. Too often treated as an afterthought, the analysis process[1] involves determining in advance the purpose for the monitoring program and who needs information for what purposes at what spatial scale and at what time intervals.

> *"The objectives of LUCID have been to put meaning to what it is that is being monitored through use of a common framework—previously there has been mostly just monitoring."*
>
> *(LUCID Participant)*

The Critical Questions

The design and implementation of a sustainability-monitoring program is intended to provide managers and the public with information to assist in understanding progress towards sustainability. Determining the purposes and uses for such a program is a key part of the assessment and one that must be done at the start of the project. This front-end assessment affects the choice of monitoring framework, the selection of indicators, the type of measures to be developed, the utility and approach to reference values and the use of technical tools such as modeling software.

The primary purpose of the LUCID Project was to develop a sustainability-monitoring program to assess the sustainability of ecological, economic, and social systems at the FMU scale. This was achieved by pursuing two objectives:

1) Test, develop, modify, and evaluate criteria and indicators; and
2) Develop methods to assess sustainability.

The crux of the challenge, then, focuses on understanding what is meant, in terms of the purpose and value, by "assessing sustainability." The secondary challenge is to discover what synthesis and analysis methods might be used to examine the relationships between indicators and to report on the results. Exploring these challenges led to the identification of the following key questions:

- ➠ What does "assessing sustainability" imply?
    - ⇨ Can a forest management unit be "judged" sustainable?
    - ⇨ Can we make a "determination" of sustainability?
    - ⇨ Does "assessing sustainability" imply a determination or a discussion?
- ➠ If sustainability implies a long-term focus, how does time factor into making a judgment, determination, or assessment?
- ➠ How does spatial scale affect the sustainability assessment?
    - ⇨ Can the sustainability of one scale be subsidized by unsustainable practices passed on to other scales?
- ➠ Can the status or progress of one forest management unit be meaningfully compared to others?

---

[1] In this chapter we refer to the analysis process broadly involving more than just the statistical processing of data.

- If sustainability is based on interacting systems that have emergent properties, can we assess sustainability if we only look at the parts?
- Can we find and use tools and approaches to help both in synthesis (to examine the complex whole) and analysis (to examine the component parts)?
- What is more useful and what is more valid for representing and communicating results—numeric scores or narrative discussions?

Synthesis and Analysis

Sustainability arises from ecological, social, and economic systems. These systems have components that interact to produce emergent properties. Synthesis refers to the combination of ideas into a complex whole. In contrast, analysis refers to the abstract separation of a whole into its constituent parts for study. Our goal was to find tools and techniques to help us look not only at the components of systems but also at the whole system.

We are not striving to construct a causal model that can predict the effects of our management actions through a small set of outputs. Instead, we are attempting to understand the interrelationships between the various components of the systems and between the systems themselves. Recognizing that there are limitations to our knowledge of these systems, we still need useful information without demanding perfect or complete knowledge.

Assessment vs. Determination

There is an inherent appeal to the idea of being able to judge or determine with certainty that some management practice or some area is sustainable. This kind of certainty would give us a great deal of comfort in an increasingly uncertain world. Being able to determine whether or not something is sustainable would seem also to facilitate comparisons. Such a determination or judgment would allow the public to be absolutely assured that governments were managing land wisely and assure managers that their choices were correct.

Clearly, the desire to be sustainable is a goal that we all share; but, as discussed in Chapter 1, the goal carries with it many meanings and a great deal of uncertainty. The various values that we hold about sustainability mean that, short of all of us sharing the same values, any determination or judgment of sustainability would be consistent only with the values held by one perspective. And the chances are at least even that this determination would be spatially biased resulting in a trade-off between one scale versus another and temporally biased with an emphasis on the needs and values of current generations at the expense of future generations.

Beyond the challenges to determination that an understanding of the variation in our values holds comes the complexity and uncertainty associated with sustainability. Even if we shared a common set of values and could therefore agree on associated targets to aim for and to assess our current status against, the complexity of sustainability and our uncertainty regarding our understanding of systems and their interactions would suggest that our determination of a state that would be sustainable would be incomplete.

If we are unable to determine something as sustainable and provide the certainty of a stamp of approval, what are our options? Through the LUCID Project the value of providing tools and processes to help managers and stakeholders assess sustainability and engage a dialogue to help make a *relative assessment* of sustainability rather than an absolute measure or *determination* of sustainability. A number of products and processes may be needed to facilitate this discussion and provide a *forum for discourse* with the public about their values of our stewardship of national forests.

LUCID EXPERIENCE WITH SYNTHESIS AND ANALYSIS

The LUCID forest teams were involved in helping develop an FMU-scale suite of C&I to assess sustainability and then to field-test these C&I using available data.

The foundation of the sustainability assessment was the premise that we assess sustainability not just by examining the parts (the individual indicators) but also by understanding the whole (the entire system). A systems framework was adopted at the outset of the LUCID Project not just to help identify a better set of indicators (the parts) but also as a

Being Sustainable vs. Managing Sustainably

There is a definite difference between an approach focused on *being sustainable* versus an approach focused on the *process of managing sustainably*. This difference recalls the discussion of whether or not sustainability is a noun or verb and the decision on the approach for monitoring and choice of the type of indicators.

A focus *of managing sustainably* is typically associated with monitoring programs (for example, the majority of certification programs) that focus on indicators of management process. The selection of these management process indicators is based on those types of management practices most thought to lead to a sustainable outcome. Judging the extent to which an organization or area complies with a set of desired management processes is straightforward and can facilitate useful comparisons, such as among competing products in a market place. The assumptions are that a management process approach implies both accurate knowledge of the best set of management practices that will lead to a sustainable state and that these same management practices can be applied consistently from context to context with the same effect.

A focus on *being sustainable*—emphasizes the use of outcome-oriented indicators. Targets (e.g., reference values) for these indicators typically need to be set in context to accommodate the differences in the structures and functions of systems from location to location and in the associated variability in human preferences for the states of these systems. The variability so necessary to ensure applicability to the location and to provide an accurate and customized picture for management

representation, a conceptual model, of the systems in their entirety (the whole). These systems representations provide a schema that allows us not just to analyze the individual components but also to synthesize across indicators to understand the whole.

This section explains some of the approaches used to assist in assessment including conceptual models, analytical techniques, and methods of representing the results. Because the process of conducting analysis and synthesis is as critical as the products and tools, this section also highlights key aspects of the process. Specific tools to aid analysis and synthesis functions are referred to briefly in this chapter but discussed in more detail in Chapter 13 and in the appendixes.

Conceptual Models

Conceptual models can provide a map to guide both the process of selecting criteria and indicators for monitoring and the process of analyzing and synthesizing results. Simply stated, conceptual models are mental maps of how things work or how things are related to each other. Conceptual models may be represented graphically (e.g., box and arrow diagrams) or in narrative form (e.g., hierarchical lists of items).

Why Develop Conceptual Models?

We all use conceptual models, particularly when we deal with complex ideas. In the development stages of a monitoring program, conceptual models can help us summarize complex ideas, communicate our understanding to others, and help focus on critical components and interrelationships. In writing about the EPA's EMAP program, the authors noted that constructing a conceptual model is an important first step in identifying indicators since they can help:

- "Link indicators to their identified value(s);
- Identify gaps and redundancies in the indicators needed to address assessment questions of concern;
- Identify indicators that can be used as surrogates for resource elements of primary concern but which cannot be addressed effectively due to data collection and measurement constraints; and
- Suggest schema to construct indices or other quantitative models for evaluating a resource's condition" (Geissler n.d.).

Although the model itself is useful as a way of communicating ideas about a complex idea to others, much of the value comes from the process of constructing it. Constructing a conceptual model involves determining how elements are related to one another. Working in an interdisciplinary fashion, teams identify connections and interactions between items. The conceptual process of integrating information needs to be nonlinear, adaptive, and iterative. Team members must "seek to make connections, develop insights, and find new ways of understanding typically separate bits of information" (Slocombe 2001).

Types of Conceptual Models in the LUCID Project

During the LUCID Project, three kinds of conceptual models were developed: 1) a conceptual model or representation of the ecological, social, and economic systems; 2) a conceptual model of the entire suite of C&I; and 3) an issue-based conceptual model of a subset of elements within the C&I. Each of these model types and various related issues are discussed below.

Conceptual Models of the Systems

The core team constructed initial conceptual models of the ecological, social, and economic systems frameworks to be used for discussing the approach and organization of the indicators with the forest teams (Chapter 7). These conceptual models were broad schematics identifying the kinds of systems and their associated structures and functions. Each of the forest teams went through the process of revisiting these systems frameworks and all adjusted them to some extent. Although few of the forest teams represented these revised systems models (the principles and criteria) schematically they did represent them in list form. In retrospect, schematic development of these systems models might have been quite beneficial particularly for those teams that struggled with particular components.

Conceptual Model of the Overall Criteria and Indicators Framework

The larger conceptual model was constructed as a relatively straightforward representation of the hierarchically ordered principles, criteria, indicators, and measures (Chapter 6). A tool (NetWeaver discussed in Chapter 13) was selected to develop conceptual models consistent with this hierarchical approach and to assist analysis (Appendix 11 presents an overview of suggestions and examples of conceptual modeling tools). How and why elements were included and related were the most important parts of the discussions. However, because most of the relationships were defined by the hierarchical relationship of C&I cross linkages were not frequently revealed in this process. Appendix 12 (electronic version only available on the CD) contains a basic NetWeaver model of the final suite of C&I.

One of the most valuable parts of the process of constructing the overall conceptual model was in prompting discussions of the relationship between the elements and spatial scale. For example, a team had to consider whether a given measure with a common reference value could be applied throughout the study area uniformly or whether spatial variation was needed in the measure or reference value. Such discussions prompted frequent reorganization of the conceptual model.

Conceptual Models of Issues

During the analysis process, each of the forest teams constructed at least one conceptual model of a management issue or subcomponent of the overall suite of indicators. For example, the Modoc Forest Team examined grazing as a management issue of concern, the Allegheny Forest Team focused on deer management, and the Ottawa Forest Team considered aspen health. Typically, the team started by identifying the subset of C&I elements most associated with the issue and then constructed a neural net of the relationships between these elements (see Figure 26).

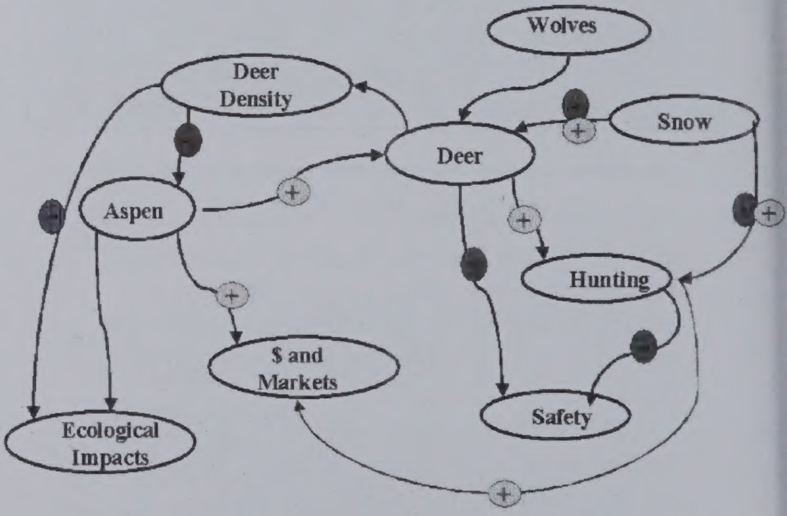


Figure 26. Conceptual Model of The Aspen-Deer Issue on the Ottawa National Forest.

Construction of these neural nets allowed the forest team to represent the nature of the relationship (e.g., direction and strength) if it was known. At a more specific level, drawing these neural nets helped in some cases to identify missing elements in the monitoring schema. Some forest teams translated these preliminary neural nets into conceptual models in NetWeaver. However, the nondirectional, noncausal relationship structure in NetWeaver meant that some aspects of these neural nets did not translate well. The construction of these issues-based conceptual models was of mixed value. Forest teams wedded to the idea of trying to convert these much more inter-related models into analytical models within NetWeaver were frustrated. Others, however, found them valuable in several ways for organizing their thoughts on a particular sub-set of components; for starting to identify means of communicating to people about the specific stories of sustainability on that forest; and for understanding the place of a specific issue or topic within the larger systems framework. In retrospect, the construction of these issue-based conceptual models would probably have been more useful if a clearer purpose and if the analysis process had not been so focused on the analytical tool but rather on the learning value. Some forest teams discussed the idea of building a broader neural net as a communications device to encourage collaborators to discuss the results and implications of the more systems-oriented analysis as it applied to a specific issue.

> *"Hierarchies were shown to be useful in analyzing issue-based questions, but were limited in their capacity to show all of the links and interrelationship between different ecological, social, and economic frameworks in our overall model."*
>
> *(Ottawa National Forest Team)*

Value and Purpose of Model Construction

Conceptual modeling was presented to the LUCID forest teams as an important step to undergo as a precursor to analysis. The conceptual model was viewed as a necessary first step in an analysis process involving the NetWeaver tool since this initial conceptual model needed to be developed and verified before reference values and data could be added and compared. Although this was true and did have value in this regard, in retrospect the development of conceptual models served many other purposes including:

- Clarifying team members' understandings of how things are related;
- Identifying areas of uncertainty including how things are related (e.g., direction);
- Identifying missing monitoring components or gaps;
- Identifying critical monitoring components (often those that served as hubs around which many elements were arrayed) and redundancies;
- Forcing team members to be specific about what and why elements were included; and
- Communicating complex ideas in more straightforward, graphic means.

> *The Value of Conceptual Modeling*
>
> *"NetWeaver was useful in forcing us to articulate our thoughts about the components of sustainability." "The conceptual modeling was good, it that you could show the entirety of the sustainability picture. It helped pare down the measures to the ones that were really critical to assess for sustainability."*
>
> *"Conceptual model building of the PCIV framework was very beneficial in aiding the thinking on the need to develop standards that were useful in evaluating data elements."*
>
> *"The NetWeaver model is a good model to conceptually display the complexities and interrelationships of sustainability, to the best of our ability to understand those complexities/ interrelationships."*
>
> *(LUCID Participants)*

Timing of Model Construction

With the exception of the initial conceptual models of systems, the bulk of the conceptual modeling was done relatively late in the project. Most participants felt that the timing was too late, particularly where construction of the conceptual models revealed a need to reorganize the suite of C&I to respond to missing elements or to truly represent the spatial implications of indicators. They suggested the need to introduce the conceptual modeling concept earlier in the

Conceptual Modeling in Mexico

In a related project on forest-level sustainability monitoring in Chihuahua, Mexico, initial neural networks were constructed by connecting sticky notes representing each monitoring element at the indicator level only (see Figure 27). These rough schematics were then translated into one of the freeware conceptual mapping tools (C-Map) so that the strength and direction of the relationships between elements could be maintained (see Figure 28). This step was conducted relatively early in the evaluation process when the forest team was just in the process of evaluating the indicators for the first time. Building a conceptual model at this point helped reveal various team members' understanding of how things were connected and was very valuable in uncovering substantial differences of opinion and understanding among team members. Translating these more complex conceptual maps into a modeling tool for analysis will be much more difficult, however, and will require the team to decide whether they want to use these initial conceptual maps solely as a discussion and communications tool and then revert to a conceptual map that can be converted to an analytical model such as NetWeaver or whether they want to search out another analytical approach.

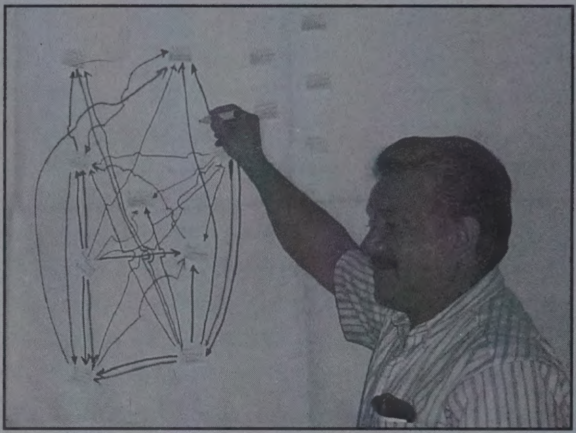
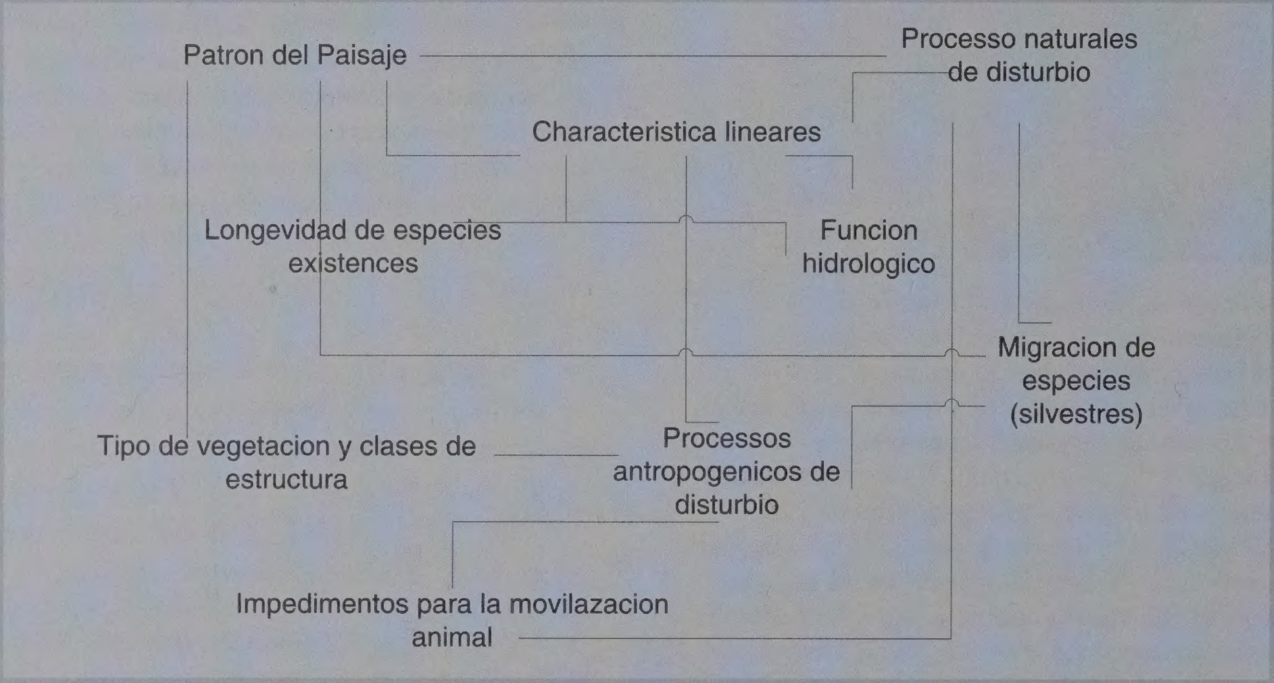


Figure 27. Developing a Preliminary Conceptual Map of the Ecological Systems



Patron del Paisaje
Processo naturales de disturbio
Characteristica lineares
Longevidad de especies existences
Funcion hidrologico
Migracion de especies (silvestres)
Tipo de vegetacion y clases de estructura
Processos antropogenicos de disturbio
Impedimentos para la movilazacion animal

Figure 28. Conversion of the Rough Conceptual Map to C-Map

process so that the teams could get the most benefit from them. The idea, benefits and process of conceptual modeling, particularly as it serves as a valuable step early in the development of the monitoring program, should not be impeded by the choice of any specific modeling tool.

Conceptual Models as Guides for Analysis

Beyond their value in the selection of indicators for monitoring, conceptual models can serve as a schema to guide analysis. Because these models represent how we understand systems work and describe the theoretical underpinnings of these systems, they can identify relationships and interactions to be probed during the analysis function.

In the LUCID Project, the forest teams' overall conceptual model built using NetWeaver was converted to an analytical model. Interrelationships between measures and indicators that had been built into the conceptual model were analyzed quantitatively when reference values and data were added to the model.

With the addition of a spatial extension to the model (Chapter 13), this analysis could be conducted either by following the schematic form of nodes and networks from the conceptual model or could be conducted spatially. The ability to move seamlessly between a schematic representation of the model and a spatial representation was viewed as a key feature of the model.

Assessment Approaches for Synthesis and Analysis

Sustainability assessment involves both analyzing the component parts and also synthesizing the components in order to understand the whole. The conceptual model of the systems frameworks, further elaborated by the more detailed conceptual models of the C&I hierarchy represent both the whole and the parts.

Examining both the parts and the whole is equally important; however, analyzing C&I frameworks has been limited traditionally to components parts, the individual indicators (see the profile on the Multi-Criteria Decision Making approach of CIFOR profiled in Chapter 13 for an exception). One key objective of the LUCID Project was to employ assessment strategies that allowed us to pursue both analysis and synthesis. General approaches are outlined in the following sections with more detailed discussions of the tools that enable this type of analysis, including their strengths and weaknesses, profiled in Chapter 13.

Indicator-based Approaches: Analysis of the Component Parts

A sustainability-monitoring program involves selecting a suite of critical indicators that focus on key elements. Such a program must include, at its most basic level, an analysis procedure that interprets the results of individual indicator assessments. This style of analysis may result in a detailed indicator profile that includes:

- An overview of the indicator and its relationship and importance to sustainability and to the study area;
- A description of the methods used to verify the indicator including any measurement or data challenges;
- Current conditions of the indicator based on available data (in spatial or non-spatial forms);
- A comparison of the current data value over time (e.g., trend data) or against some other reference value (e.g., a benchmark); and
- Possible management implications.

This approach is not only the most common to sustainability C&I initiatives but it is also typically the sole approach for analysis. As the fundamental unit for monitoring, indicator-based analysis is a necessary prerequisite for other forms of analysis. The resulting detailed indicator profiles are very useful in providing specific feedback to assist day-to-day management and to provide a database of reference information.

Within the LUCID Project most of the forest teams prepared summary indicator assessments with specific focus on indicators or measures of concern (see Figure 29). In most cases time precluded the preparation of these more detailed profiles although teams indicated that this would

☑ C3.1 Capital and Wealth

☑ I3.1.2 Change in Asset Value of Manufactured Capital (over 10 years)

All three verifiers under indicator I3.1.2 greatly exceeded the standard (in a positive way) of a 15 percent increase over the 10-year period analyzed (1990 to 1999). The asset value of roads increased 245 percent, the asset value of campgrounds increased 160 percent, and the asset value of trails increased by 99 percent. The past 10 years have seen a great deal of investment in roads, campgrounds, and trails on the forest. This level of investment is probably not likely to be sustained over time. It is also possible, even likely, that we have under-estimated depreciation rates for these assets, and that net investment levels have consequently been over-estimated. Working out accounting methods for this verifier is a research need. In any case, the data values are credible. Roads and trails on the forest are much better than they were 10 years ago. There still is a sizeable maintenance backlog for the campgrounds, but it is much less than what it was 10 years ago.

Source: Adapted from Allegheny National Forest LUCID Team Report

Figure 29. Example Indicator Summary

be useful in the future. Most of the indicator assessments tended to report the results organized by principle and criteria with details provided on measures that did and did not meet reference values.

This approach to analysis and presentation was relatively easy for the reader to follow, especially if the reader focused on the list of C&I as the basis for the sustainability assessment. For these reasons alone this approach to organizing the sustainability assessment will probably also have great utility.

Systems-Based Approaches: Synthesis of the Component Parts

One key weakness of an indicator-based analytical approach is the difficulty in highlighting and analyzing interrelationships between indicators. The individual indicators examined in a component-by-component approach do not capture the emergent properties of systems. Examining the interactions critical to understanding sustainability is more difficult when indicator-by-indicator profiles, often of a suite of 30 to 60 indicators, is the sole analytical tool. By itself any one indicator is only a component of understanding a system and a small signal in the overall assessment of sustainability. Indeed a given indicator may well be out of compliance with a reference value. Examined in isolation the signal that comes from that indicator may be incomplete. The true signal comes from probing how the indicators work together as a suite to assess the status of a system's structures and functions. The image that comes from the assessment of the whole system can help signal whether a negative trend in one indicator is having an effect on the overall system.

Systems-based assessment works to synthesize the results of individual measure and indicator assessments within the framework of the structures and functions of systems.

This synthesis is not an automated function, however. Part of it is achieved from framing the examination of indicators within the systems context. Part of it is achieved by pursuing analytical tools that synthesize the evaluations of individual indicators into groups based on these systems frameworks. However, given our inability to construct true causal-analytical models of all of the interactions and feedbacks within these system frameworks the largest part of the synthesis function comes from people. In this sense we can use the systems frameworks in conjunction with the results of the individual indicator assessments and the synthesized assessments to inform our discussions and dialogues about the state of systems.

Synthesized evaluations of indicator assessments provide a tool to help accomplish systems-based assessments. This type of analysis works with the individual indicator assessments but organizes them and examines them within the systems framework. In the LUCID Project we selected a hierarchically based expert-knowledge modeling program (details are provided in Chapter 13) to facilitate synthesis of results. Using this approach, we combined the individual evaluations of groups of measures and indicators within a range of possible algorithms to produce a synthesized evaluation of the critical indicators associated with that system component or function (see Figure 30).

The Role of Frameworks in Analysis

In their development of a C&I framework, the International Tropical Timber Organization (ITTO) formulated criteria as a "subject of attention" but did not use them to describe a state or situation desired for sustainable forest management. Appanah and Kleine (2000) note, therefore, that: "ITTO's formulation as such can only be used for reporting purposes on individual parameters. It cannot be used for assessing or evaluating a particular state or condition at the level of the criterion."

Spatial Extensions

The highly spatial nature of the resource management challenges associated with forest sustainability makes spatially based analytical approaches highly desirable. Among their key features they:

- Provide a broad overview, with spatial variation, of the assessment of an indicator compared to its reference value (or similar aggregated analysis at other levels of the C&I hierarchy);
- Pinpoint areas for further analysis or examination;
- Communicate with a broad range of audiences;

Land Ownership, Access, and Value

Based on underlying verifiers [for this criterion], we can make the following observations:

☑ The current mix of timberland owners in the western Upper Peninsula of Michigan and bordering Wisconsin is changing, affecting opportunities and conditions for future forest uses.

☑ Public land ownership has increased over the past decade by 5 percent to 2.7 million acres.

☑ Forest industry ownership decreased by nearly 20 percent and private/non-forest industry ownership increased by about 20 percent. This exceeds our benchmark for maintaining near-existing conditions related to timber supply and access. (Forest industry land refers to timberland held by mill owners. Nonforest industry land may also be managed for timber yields.)

☑ Parceling and length of land tenure are changing. There are more owners of smaller parcels who hold their lands for a shorter time period. Additional information differentiating permanent from seasonal residents would be helpful. FIA data on landowner use would also help reveal changing owner goals.

☑ Accessibility to Ottawa National Forest lands for public uses has changed little over the past 10 years.

☑ Public lands have increased <10 percent since the 1980s.

☑ Forest industry and non-forest industrial land available for public access is nominally the same over the past 10 years; however, more limitations on use and fragmentation of parcels have reduced the net land available.

From these observations, we can make tentative conclusions or interpretations, as follows:

☑ There appears to be a shift toward less forest industry land ownership, and more private, nonforest industrial ownership and stable public land ownership.

☑ Additional private owners bring expectations for access, services, and management conditions on adjacent public lands.

☑ Where private-public lands intermingle, management activities and uses on public lands may become restricted, affecting the ability of public lands to supply recreation or timber management opportunities.

☑ It is likely that private land values will continue to increase and public lands will also increase in value as substitutes become more limited.

Figure 30. Narrative Discussion of Interrelationships: Ottawa Forest Team Discussion Points for a Social Criterion

- Perform detailed analysis on specific geographic units (e.g., watersheds, wilderness areas);

Although few C&I initiatives have utilized a unified model for analysis that is spatially based, many utilize spatial analysis to examine individual indicators. An increasing number of institutions are studying the potential for developing similar integrated models (see, for example, the MCDM and EMDS approaches profiled in Chapter 13). A unified, spatially based tool maps the evaluations of the indicator comparisons against reference values based on the spatial units associated with that indicator. GIS spatially based analysis techniques can then be used to examine the distribution of values and to assist in synthesizing the results across spatial scales. A truly integrated spatially based tool will be able to map the results of the synthesis at each level of the systems and C&I hierarchy.

Several forest teams noted that they found one of the most valuable uses of spatially based approaches was to help identify areas for closer examination. They referred to this as the process of identifying "red" and "green" flags and used this as a means of targeting their more detailed analysis or examination of the data (Figure 31).

Perhaps because of the enormity of the study area and because of their extensive previous use of GIS supported techniques, the Tongass Forest Team organized much of its analysis by geographic area first and then pursued other types of analysis (e.g., indicator-by-indicator or issues) within that framework (see Figure 32).

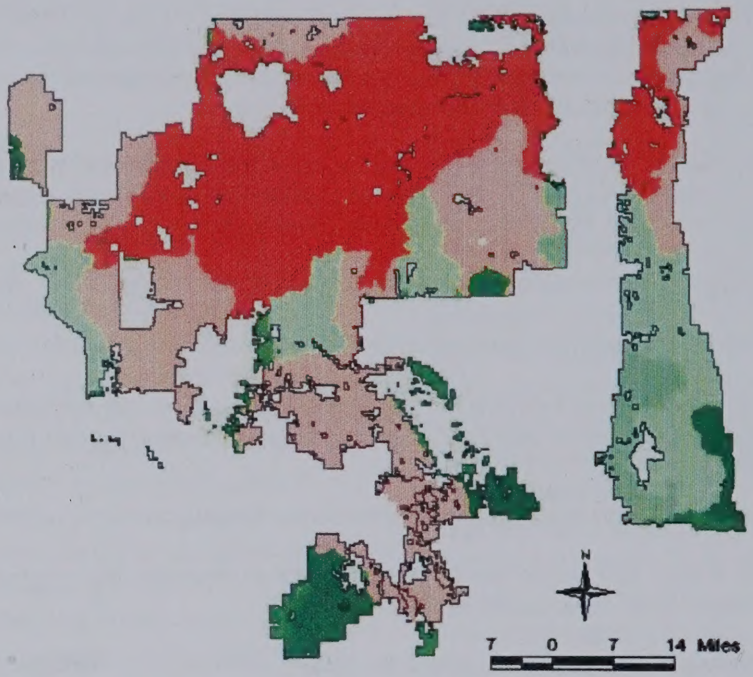


Figure 31. Display of Spatial Variation of a Hypothetical Indicator Compared to its Reference Value

Key: Dark red is complete nonattainment of the reference value and dark green is complete attainment of the reference value.

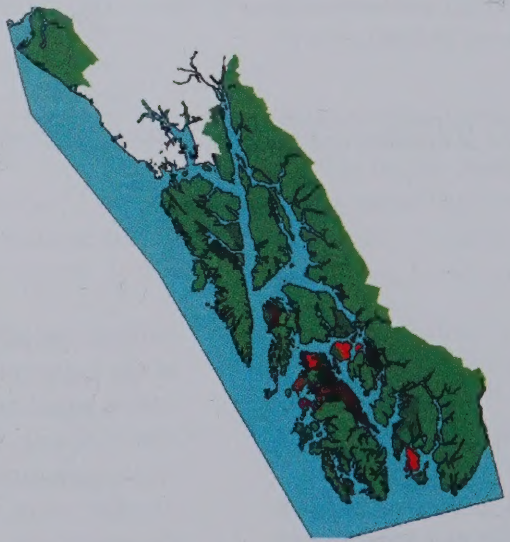


Figure 32. Tongass National Forest Display of NetWeaver Results from the Social Principle

Key: Shades of red (does not meet reference value), black (neutral value), green (meets reference value). White areas are outside the unit of analysis.

Synthesis Questions as a Basis for Analysis

Analytically, the synthesis and interactions between elements can be pursued not just by systems-based analysis but by specifically targeting analysis on a set of hypotheses or questions about these interrelationships.

The core team developed a partial suite of questions for economics that might be used as a way of analyzing across various indicators and verifiers and presenting results. These questions were developed based on revisiting the fundamental tenants of economic systems and trying to identify key axioms of sustainability from an economic perspective (see Table 22). Using this approach allows the analysis and interpretation of results of the C&I to be nested within these overall questions. Forest team members suggested that assembling a suite of possible questions to guide analysis would be a useful addition to the tools provided to future forests.

The Need for Further Development

Most forest teams noted that their analysis and discussions focused on the details; and they needed to spend more time, particularly in interdisciplinary discussions, in understanding the implications of the state of the system. Using a common systems framework between national forests can improve consistency not just in the monitoring elements themselves but in the analysis and reporting of results.

Although the use of a systems approach greatly improved the theoretical basis behind the selection of indicators relative to their ability to assess the sustainability of systems, there is a recognized need for the study and development of additional analytical tools and approaches to truly pursue the interactions.

Analysis and Synthesis with Numbers and Narratives

Both the analysis of individual indicators and the synthesis of indicator evaluations across systems structures and functions rely on taking the results of quantitative assessments and interpreting them in meaningful ways. The relative roles of quantitative techniques (numbers) and qualitative techniques (narratives) parallels the discussions of analysis versus synthesis.

Numeric reporting can be very useful to quickly summarize complex information. In

Table 22. Sample of Possible Key Questions to Guide Economic Analysis

- Is there a sustained flow of environmental services and products?
- Are we living off the interest of renewable resources?
  - Are we minimizing the use of renewable resources?
  - Are investments made in the natural capital?
- Is there a positive economic trade balance?
  - If the trade balance is positive, is it positive because capital stocks are being depleted?
  - If the trade balance is positive, is it positive because human capital is being depleted?
- Is built capital a substitute for natural capital?
  - Is this efficient?
  - Is the decision (substitution) irreversible?
- Does the community have the human capital resources to meet its demands?
  - Are we investing in improvements to the human capital to meet anticipated needs or changes?
- Is the community resilient to changes and fluctuations?
  - Is the economy diverse?
  - Is population age distribution stable?
- Is the physical infrastructure of communities diverse, being maintained or extended?
- Are benefits and costs of natural resource use and environmental protection equitably (fairly) distributed?
  - Socially? (e.g., between groups of people)
  - Geographically? (e.g., not one community at the expense of another)
  - Is the distribution of incomes equitable?
- Are economic subsidies (e.g., the need for) from outside the area decreasing? (e.g., Federal wealth redistribution systems)

Forest Team Suggestions for Further Analysis

During the test, the Blue Mountains Province Forest Team developed a set of key questions to help guide their assessment. They believe it might be useful for presenting some key messages to stakeholders and to help guide future analysis.

1. What is the baseline condition of the economy and the quality of life in Union and Wallowa counties, and what factors and trends (natural resource management, economic development, agricultural production, etc.) are affecting these conditions?
2. What key assets and business and workforce capacity are available for ecologically sustainable economic development?
3. What opportunities exist or are forthcoming to utilize local skills, businesses, and resources to address ecosystem restoration needs and create by-products or value-added opportunities from restoration?
4. How can investments in community-based watershed restoration lead to improvement in the management of landscapes, generate economically viable local employment and income, or improve the socioeconomic conditions?

The Ottawa National Forest Team also provided a list of possible types of analysis that they thought were worth considering.

1. **Vital-Sign Analysis**
   Assess suite of key system indicators against standards.
   This assessment trigger more indicators.
   Key indicators chosen to demonstrate that desired standards are being met.
   Key indicators could be picked because they are:
   - Important management or public issues.
   - Closely linked to other ecosystem attributes.
   - Signal risk to long-term adaptability of ecosystems.
   - Signal short-term changes to economy.

2. **Threat-Set Analysis**
   Assess those not currently meeting benchmarks or most likely to be unsuccessful in future or those on the cusp of not meeting benchmark.

   Those in latter category could have weights added to represent different levels of importance.
   - Weights could be added to represent levels of danger.
   - Weights could be added regarding certainty or reliability of data.
   - Risk also incorporated reflecting probability that data values may change over short term.

3. **Forest Plan Baseline Analysis**
   Assess change in key indicator values since implementation of plan in 1986.
   Could do a subset of those indicators from forest plan, and with a special analysis against forest plan standards.
   Could then determine if analysis from LUCID standards add value.

4. **Short-Term/Long-Term Standards**
   Compare standards for short-term effects vs. long-term resiliency.

reality, however, these numeric scores have no meaning in absence of the richer discussions and context that surrounded them. Reporting results this way, either verbally or in print (even to other Forest Service staff who are not familiar with the tools never mind the public at large), particularly when they are presented without explanation or discussion is very problematic. Not only are the numeric values difficult to understand but they can be very misleading.

Numeric approaches allow us to synthesize and summarize complex phenomena, to combine elements, and to make comparisons. Consequently, as more complex analytical tools such as models are utilized (Chapter 13) to facilitate the comparison of data against reference values and to pursue the relationships and interactions between components and report on the state of the whole system and not just its parts we increasingly rely on numeric approaches. Although models and other analytical tools may be based on mathematical algorithms they may not be the most appropriate results to report.

Clearly, mathematical values are useful in generating the information to inform the discussion; but to facilitate understanding of the meaning and issues associated with monitoring, rich narrative discussion is most useful. Narrative approaches provide rich description with the detail and explanations, the cautions (e.g., missing data), and the potential controversy that readers should be aware of. Narrative approaches need not be written from a singular perspective but can raise alternative perspectives and values generating comment and discussion. This approach is exceedingly flexible and can vary with the audience or by purpose.

For the LUCID Project we selected a modeling tool, NetWeaver, to facilitate the analysis process by comparing data against reference values. Results were normalized on a standard scale from full attainment of the reference value to complete non-attainment of the reference value. Networks of these assessed values of related items could be combined with a variety of different algorithm techniques. The NetWeaver tool and these normalized values (NetWeaver scores) that resulted from it were very useful in processing large quantities of data, in normalizing the values on a common scale, in displaying the spatial variation of the results, and in aggregating it to assess the status of a group of related phenomena. However, as the previous discussion illustrates the numeric values are relatively meaningless unless they are interpreted.

> *"Narratives have a similar power in their ability to make equivalent otherwise disparate relationships which may not be dynamical or quantitative."*
> *(Allen et al. n.d.)*

During the LUCID Project, participants showed a tendency to refer to the NetWeaver scores, incorrectly, as sustainability scores. Concern was expressed that aggregated numeric values, particularly at the highest levels of the C&I hierarchy, would be used potentially in a comparative way as a statement of the "degree" of sustainability. As a result, we considered selecting or redesigning a tool that did not use numbers to calculate the result or at least

When is a Number Meaningful?

An indicator of deer population numbers may receive a positive value of .75 when compared to its reference value (meaning that the current data represented a 75 percent attainment of the reference value or standard set for deer population numbers). But whether or not we should be happy with a .75 value is a much deeper subject that involves an examination and discussion of many factors. What context are we looking at deer population numbers from? Hunters may be satisfied with high deer population numbers, but what is the relative affect of deer browsing on seedling regeneration? What is the interactive effect of deer population numbers on other variables? How accurate and reliable are the data? What is the spatial variability of deer population numbers? Are deer distributed uniformly across the forest, or are there troublesome pockets of lower and higher populations? What is our comfort and reliability with the reference value we've set? Do we have reasonably accurate information on deer survival, on hunter satisfaction, and on seedling regeneration or was this reference value set in a preliminary fashion and needs to be studied further? What are the data trends? Were deer population numbers closer to the reference value last year, and we are now on a downward trend; or is the trend positive? What is the rate of change and to what extent can the Forest Service by itself influence the outcome or does the Forest Service rely on cooperative management from other organizations such as State Department of Natural Resources who may not share the same management targets or objectives?

suppressed the numbers at the higher levels of the hierarchy. However, the approach proved beneficial in synthesizing large quantities of spatially variable data, in facilitating the assessment of an indicators status against a range of reference values, and in normalizing the results so we could talk about them collectively. This allowed us to combine the results in ways that improved our ability to talk about higher order concepts. We were loath to abandon this simply because someone might be tempted to use the tool in the wrong way. Instead, we recommend that these numerically based models can be very valuable in facilitating a discussion about a relative assessment of sustainability. We suggest that the presentation of results should predominantly be narrative in nature and supported by cautiously interpreted values. If a modeling based tool is used, users should refrain from reporting the numerically calculated values at the higher levels of the C&I hierarchy or do so only with a great deal of explanation, caution, and interpretation.

With a narrative approach it is much easier to tie in interrelated information from other indicators or measures. This is particularly important where we lack the ability to build full causal models of the predictive relationships between indicators that could be pursued mathematically. In these situations the possible relationships between indicators can be examined along with the uncertainties about the strength and nature of the relationship and any intervening factors. When the focus turns to discussing the emergent properties of systems or how ecological components interact with social and economic components, narrative approaches can help pursue these synergistic effects.

Rich narrative approaches also facilitate the discussion of results across spatial scales. For example, should the value of a high unemployment level be uniformly applied across an entire county if the unemployment phenomenon is most heavily associated with the rural versus urban parts of the county? If it is useful to present a countywide average for unemployment, what kind of explanations or cautions need to be presented? Providing linkages between the scales of study of sustainability is clearly desires however, a reliance on numeric tools tends to make it easier and more appealing to aggregate results even when they should not be aggregated. In these situations a narrative approach can provide an explanation and the context necessary to enable some meaning to be related from scale to scale and alleviate some of the scale-dependent data aggregation concerns that we encounter when we work with numbers.

Clearly, the presentation of results need not rely on only one technique. Indeed, to facilitate understanding complementary use of narrative explanation with charts, graphs, or maps displaying numeric summaries will most effectively communicate the results.

Although forest teams organized their results in a range of different ways (by criterion or indicator, by management issue, or by physical areas or ecoregions), by far the most popular and meaningful method of presenting results was a narrative description of the results. These narrative descriptions varied but included things such as definitions of the indicator or measures involved; a discussion of the standards set; a description of the data or at least specific pieces of data of concern or interest; a discussion of missing data; potential causal influences; and tentative management implications (see Figure 33).

- ☑ Selective Pressure: Red because (a) some grazing strategies are resulting in selective pressure on riparian hardwoods, which is selecting against palatable species such as Geyer willow plus Booth and Bebb willow which have been extirpated in many areas; and (b) because of selective pressure against genetic diversity in aspen stands because of grazing practices and conifer succession.
- ☑ Possible management implications, assuming standard is accepted: Where needed, adopt grazing practices that do not have the effect of simplifying or eliminating riparian hardwood or aspen communities. Restore aspen clones by using appropriate grazing practices and targeting stands for conifer removal to maintain the genetic diversity of this forest community. Consider augmenting riparian hardwood diversity with plantings.

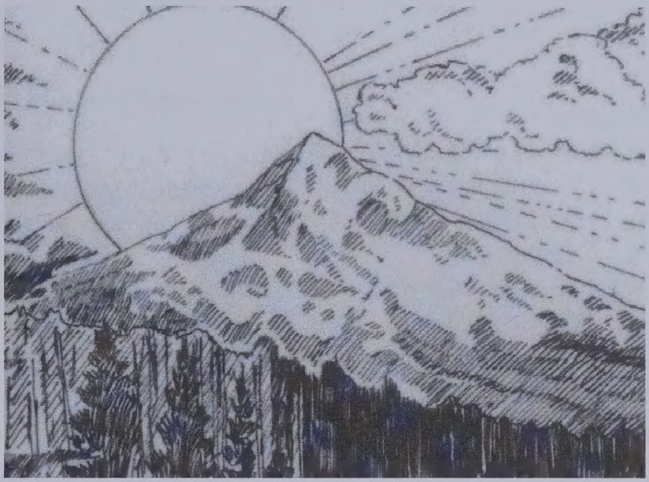
Figure 33. Modoc National Forest: Example Ecological Indicator Narrative with Management Implications.

CHAPTER HIGHLIGHTS

- Ensuring that a monitoring program is useful involves the functions of synthesis, analysis, interpretation, and presentation so that monitoring data is converted to useable knowledge as part of the broader adaptive management process.
- Synthesis refers to the combination of ideas into a complex whole. In contrast, analysis refers to the abstract separation of a whole into its constituent parts for study. Our goal was to find tools and techniques to help us look not only at the components of systems (the parts) but also at the whole system.
- The goals of synthesis and analysis within the LUCID Project are to help managers and collaborators engage in a dialogue to help make a *relative assessment* of sustainability rather than an absolute measure or *determination.*
- Conceptual models are mental maps of how things work or how things are related to each other, and they can provide a map to help guide both the process of selecting criteria and indicators for monitoring. They can help clarify understanding, identify areas of uncertainty; identify critical components, missing elements, redundancies, and communicate complex ideas in simple ways.
- Beyond their value in the selection of indicators for monitoring, conceptual models can serve as a schema to guide analysis and identify relationships and interactions to be probed during synthesis and analysis.
- At the most basic level, the analysis of the results of a sustainability-monitoring program involves interpretation of the results of the individual indicator assessments.
- A key weakness of an indicator-based analytical approach is the difficulty in highlighting and analyzing inter-relationships between indicators. Individual indicators analysis does not capture the emergent properties of systems.
- Systems-based assessment approaches work to synthesize the results of individual measure and indicator assessments within the framework of the structures and functions of systems.
- Synthesis is not an automatic function. It is a result of examining indicators within the systems context, synthesizing the evaluations of individual indicators into based on these systems frameworks and interdisciplinary discussions and dialogues about the state of systems.
- Spatially based approaches to synthesizing individual indicator assessments are highly advantageous for resource management.
- Although models and other analytical tools may be based on mathematical algorithms, they may not be the most appropriate results to report. Narrative approaches provide rich description of detail and can help synthesize across system components, reveal emergent properties, and facilitate the discussion of results across spatial scales. The presentation of results should predominantly be narrative in nature supported by cautiously interpreted values.

CHAPTER 13.

ASSESSING SUSTAINABILITY: ANALYTICAL TOOLS AND ISSUES



BACKGROUND 205

- *Sets the context for the discussion of technical tools for analytical purposes.*

KEY FEATURES 205

- *Reviews each of a set of desired key features for analytical purposes and discusses the experience of the LUCID forest teams for each of those features.*

IMPLICATIONS 226

- *Summarizes the implications of using technical tools to assist in assessing sustainability and suggests the need for further development.*

> "[I]t is not enough to choose indicators having some correspondence with meaningful attributes of the object studied. In addition, it is necessary to insure that some minimum correspondence exists between the functional inter-linkages among the attributes and the procedure linking or aggregating the individual indicators. A set of indicators (variables) and a set of assumed relations among them constitute a "model" of the original system."
> (Gallopin 1997)

BACKGROUND

As the previous chapter illustrates, the analytical approach to assessing sustainability is a broad process of organizing and thinking about the theoretical underpinnings for synthesis and analysis. It involves addressing what information the user needs, what kinds of decisions will be made with the information, and how monitoring information can be analyzed. In short, assessment is a process that starts from identifying the initial objectives of the project to reporting the decisions at the end. Analytical tools are the technical instruments that can be used to help in this process.

While Chapter 12 discusses broad purposes and approaches to sustainability assessments, this chapter is more technical in nature. Appendixes contain additional supplemental information.

KEY FEATURES

There are a variety of specific technical needs for an analytical modeling tool to be useful in sustainability monitoring and assessment. This chapter is not intended as a formal presentation of the results of an information technology requirements analysis. The approach to synthesis and analysis in the LUCID Project was much more iterative than that. Early in the project, we recognized the need for tools to help us with a range of tasks from organizing information to helping us understand reference values, to working with data at multiple scales, to helping synthesis relationships in data, to presenting the results (see Table 23).

Although some of these specific attributes were anticipated prior to selection of a trial modeling program, the importance of these and other attributes emerged through the project.

This chapter is structured in a format of parallel sections, each of which contains a brief description of a key attribute and is complemented by an overview of the features and abilities of the NetWeaver software used within the LUCID tests. Other technical tools and modeling programs are profiled throughout to illustrate options and alternative approaches.

Table 23. Desired Key Features

	Desired Features
☑	Knowledge/logic-based model
☑	Hierarchically based
☑	Object-oriented
☑	Spatial application
☑	Fuzzy/discrete values
☑	Weighting
☑	Treatment of missing data
☑	Capable of working with an incomplete model
☑	Transparency
☑	Documentation
☑	Interactive/adaptable
☑	Synthesis capabilities

Knowledge/Logic-Based Models

Given the complexity of the sustainability topic and the limited knowledge about how the ecological, social, and economic systems work constructing a causal/predictive model that would reduce the relationships between a limited number of variables to mathematical statements (e.g., linear programming optimization approaches) is not feasible or desirable. Instead, we wanted a modeling tool that would help us portray the complex, multidirectional relationships among a large number of variables to help guide in the process of specifying what was important and to identify pathways for analysis. And while a few mathematical relationships were known, we wanted to be able to represent our understanding of how things were related and functioned as a set of systems. The tool needed, then, to be able to work with a large number of variables with multidirectional interactions and a great deal of uncertainty as to the nature, direction, and strength of those interactions.

Knowledge-based, or logic, models are constructed around a set of propositions and the associated components and their logical interactions. Professional knowledge (expert judgment) rather than mathematical relationships are used to describe the relationships between the variables in the model. Though the initial proposition (e.g., forest ecosystem sustainability) is abstract, the components or topics (e.g., ecological, social, and economic systems) that underlay it at each successive step provide increased specification and precision. Knowledge-based models can be built interactively by asking a set of experts to identify components and interrelationships among components. Ideally, knowledge-based models should be able to graphically represent the identified relationships as well as support mathematical analysis.

Our understanding, our knowledge base, about sustainable systems was represented through a series of conceptual models (Chapter 12). Consequently, an analytical modeling tool that could mirror our conceptual models was highly desirable.

Knowledge-Based Model Components in NetWeaver

NetWeaver is a knowledge-based or "expert," system. Because much of what we want to model is poorly understood we have adopted an analysis tool that takes this into account and uses the current knowledge of disciplinary or domain experts to construct a sustainability model. Relationships and linkages are not generated by the model but rather are explicitly defined by the user. In the LUCID Project members of the forest teams and external partners served as the experts to model their concepts of the social, ecological, and economic systems within sustainability.

NetWeaver models have a series of fundamental building blocks. Propositions are represented as goals and an associated group of goals built into a dependency network. If the goal is to *maintain ecological integrity,* the associated dependency network consists of subgoals including *ecosystem structure and function, organism structure and function, landscape structure and function, and population structure and function.* Each component of these dependency networks has further dependency networks below it. For example, the criterion *landscape function* depends on a network consisting of indicators including *disturbance processes, hydrologic function, and long-term community dynamics.* At the finest degree of specification, the dependency network of a measure (indicator: landscape patterns; measure: patch size and shape metrics) depends on a series of data elements (mean patch size and edge to interior ratios by forest/nonforest area, by successional stage, by vegetation community type). Each of the data elements is associated with data values in a data set and a reference value that it can be compared against.

Dependency networks and data elements can be combined with a variety of logical operators depending on the fundamental basis of the proposition. If an *AND* operator is used, it implies that the proposition *maintain ecological integrity* depends on a combination of *ecosystem structure AND landscape structure AND organism* *structure.* If an *OR* operator is used, then the proposition depends on either one *OR* the other attached component(s). A "SEQUENTIAL OR" *(SOR)* operator expresses a preference in an *OR* relationship such that the preferred component is the left (top) component. However, if the information for that component is incomplete it defaults to the right hand (lower) component. Various refinements and options in logical operators have been developed to express different mathematical relationships between the components that are discussed in the fuzzy logic and aggregation sections of this chapter (see Figure 34).

Within NetWeaver the knowledgebase is first constructed as a conceptual model and then in later stages converted to an analytical model through the addition of data and reference values.

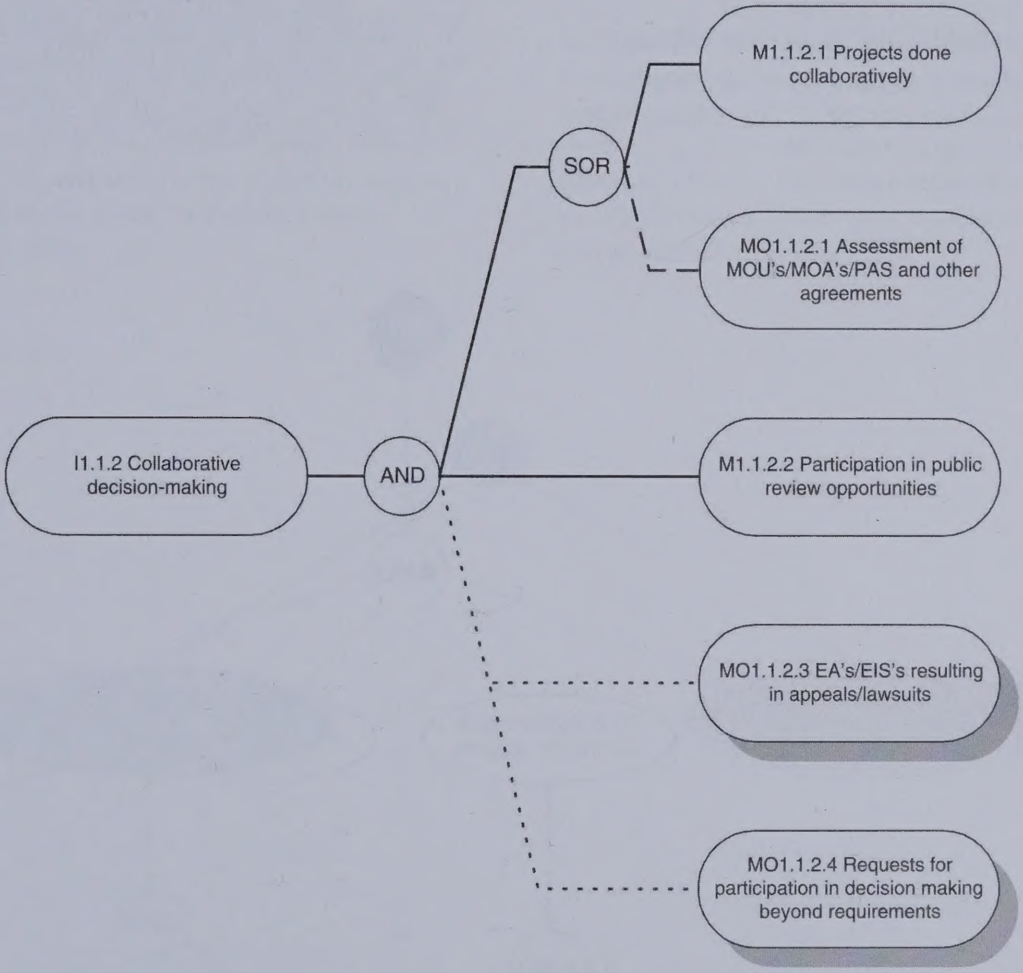

M1.1.2.1 Projects done collaboratively
SOR
MO1.1.2.1 Assessment of MOU's/MOA's/PAS and other agreements
I1.1.2 Collaborative decision-making
AND
M1.1.2.2 Participation in public review opportunities
MO1.1.2.3 EA's/EIS's resulting in appeals/lawsuits
MO1.1.2.4 Requests for participation in decision making beyond requirements

Figure 34. Example LUCID Dependency Network

Hierarchically Constructed

A key desired feature of an analytical tool is the ability to build and display the hierarchical relationships of the nested set of objects. The C&I represent a hierarchical framework in which each element (for example a criterion) is a proposition supported by a series of detailed logical specifications (e.g., indicators). Each component of a C&I framework from principle through criterion, indicators, measures (PCIM), data elements, and reference values are hierarchically nested.

Hierarchical Attributes of NetWeaver

NetWeaver is a hierarchical model. It allows the user to construct and display the relationships between the objects at each level in the hierarchy (Figure 35). Because the PCIM model (Chapter 11) also shares this type of structure, NetWeaver actually assists in the model construction. All of the teams used NetWeaver while developing their conceptual models. The place that an object (e.g., an indicator) occupies in the hierarchical decision tree helps to define how that object relates to other objects. It also allowed the teams to logically group, or nest, objects. However, it is difficult to visualize and display linkages across branches of the hierarchy. A network configuration would probably allow an easier link between model components but would force the model developer to create the PCIM structure within the network. It may also be more difficult to maintain and display these models.

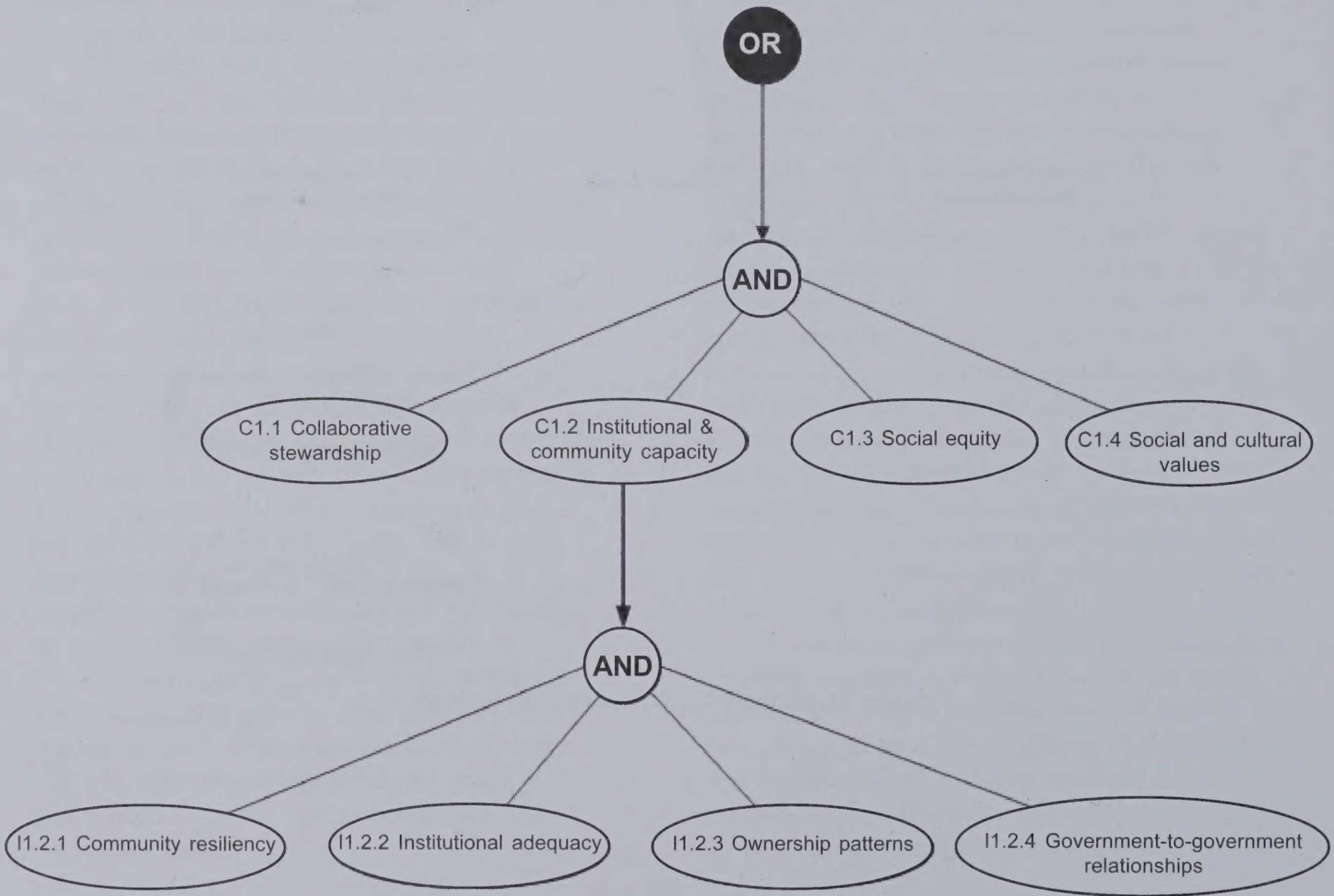

OR
AND
C1.1 Collaborative stewardship
C1.2 Institutional & community capacity
C1.3 Social equity
C1.4 Social and cultural values
AND
I1.2.1 Community resiliency
I1.2.2 Institutional adequacy
I1.2.3 Ownership patterns
I1.2.4 Government-to-government relationships

Figure 35. Hierarchical Representation of the PCIM within NetWeaver

Object-Oriented

Object-oriented models are those that give a unique set of properties to each element in the model. Each model component (e.g., a principle, criterion, indicator, or measure) becomes an object; and because the properties of each object don't depend on where it is in the model, an object can be moved from one location to another either during the model development or in subsequent analysis. Within object-oriented models objects may also be used in multiple places. This feature allows the user, for example, to use a common data element (e.g., deer population numbers) but evaluate each object against different reference values in any, or all, of the social, ecological, and economic components of the larger model. The object-oriented feature also allows the user the ability to regroup various components of the model to explore specific management issues.

Object-Oriented Attributes of NetWeaver

NetWeaver is an "object-oriented" model so model components either individually (e.g., a data element) or together (a dependency network of related elements) can be used in more than one place in the model (Figure 36). A specific advantage of the NetWeaver application is that a unique reference value can be attached to the object each time it is used in the model. This object-oriented feature is helpful in building interrelationships between components or principles of the model and is also useful in analysis. The user can perform a unique analysis, for example, an analysis of a particular geographic area or subset of management issues, by rearranging the model based on selecting only a subset of objects. The object-oriented nature means that a new model does not have to be built and populated with data again.

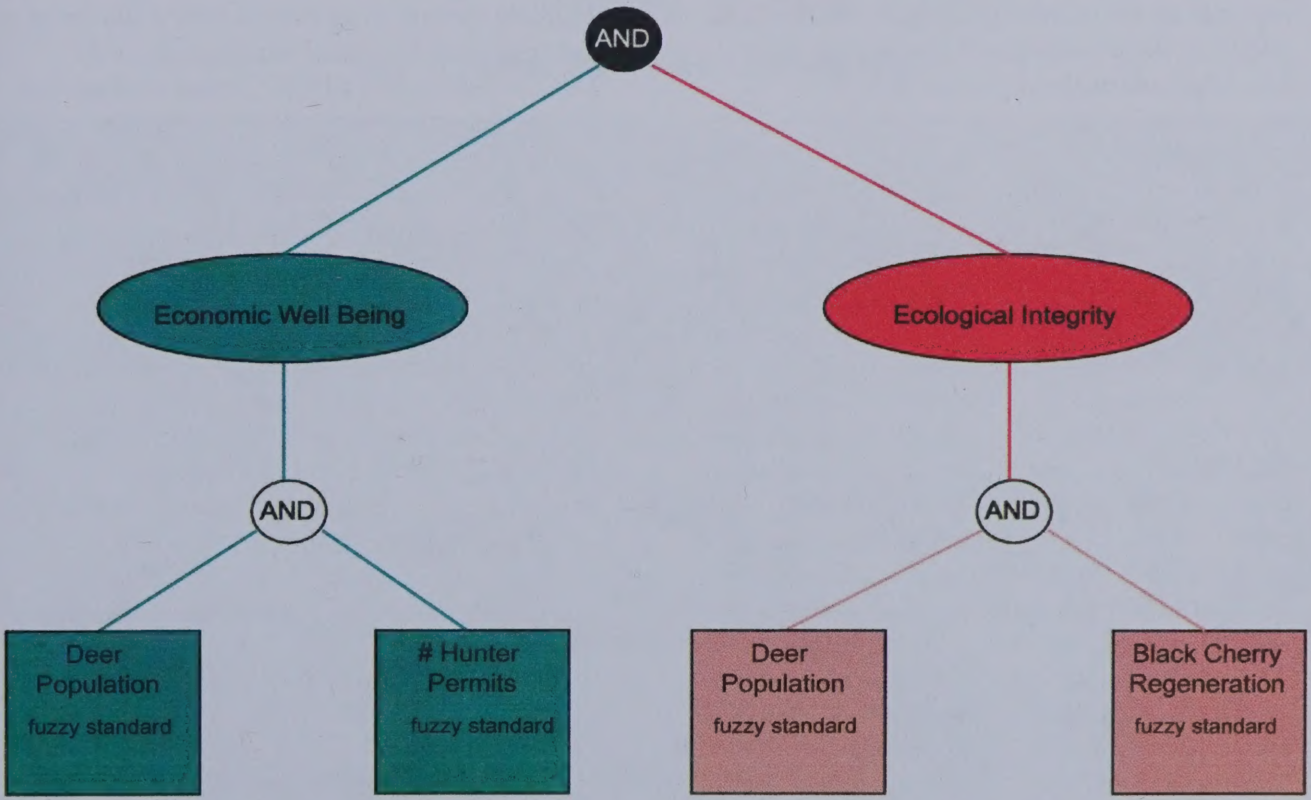


Figure 36. Object Oriented

Spatial Application

Most applications of C&I, regardless of scale, provide insights on sustainability of forests but are expressed over the whole management/study unit, "and are not spatially referenced" (Mendoza et al. n.d.). For management purposes, "especially in the context of adaptive management, it will be useful to devise a spatially explicit expression of the assessment of sustainability" (Mendoza et al. n.d.).

Because ecological, social, and economic systems are multiscaled, sustainable forest management requires spatial information and spatially based decisions that can work at multiple scales (Chapter 3). There is, however, no common set of spatial units within or between system components. Although disturbance regimes such as fire may be best measured and analyzed at larger spatial scales, other disturbances are small-scale in nature. Not only are the questions, data, and systems multiscaled; but the fundamental units of measurement and analysis are not common. Questions about hydrologic function and watershed condition may be best asked and analyzed on the basis of watersheds while questions about employment and income may be best asked and analyzed on the basis of communities or counties.

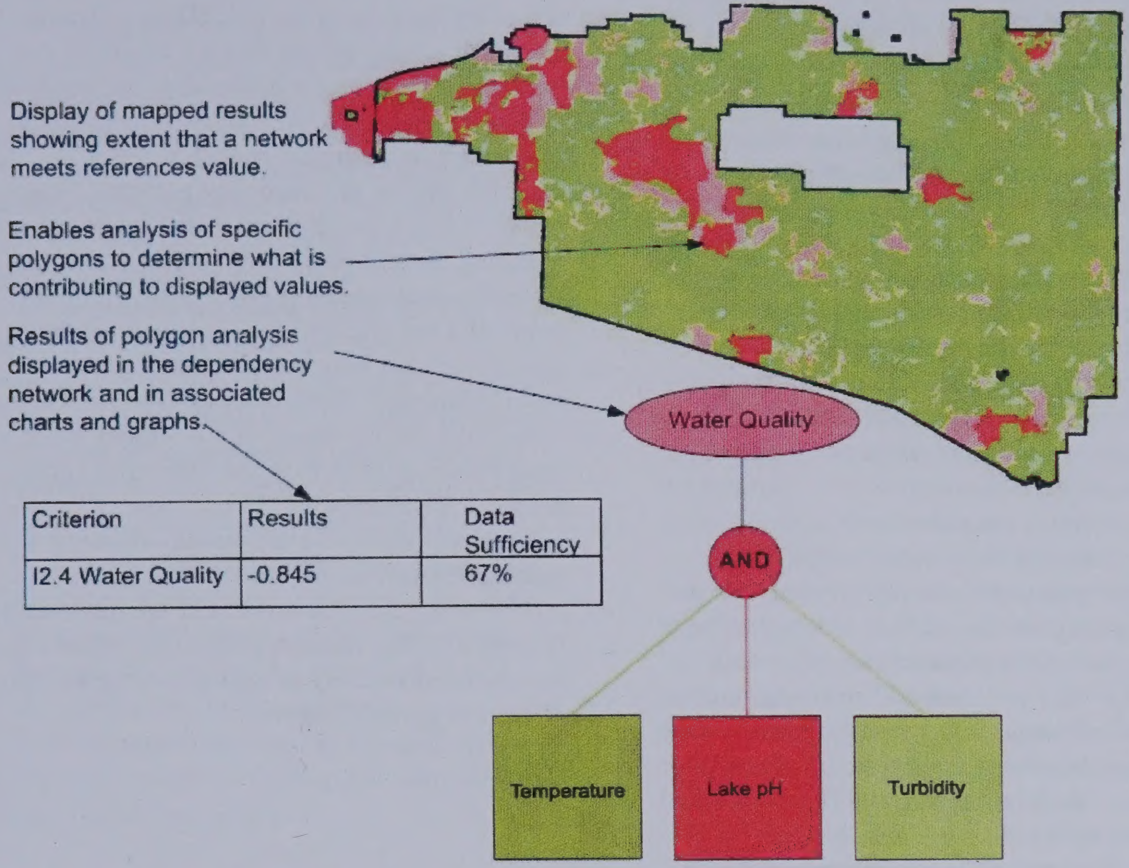
Another component of the scale question has to do with the grain of the information. While scale describes the extent of the geographic area, grain describes the breakdown of information within the area (Chapter 2). It is like looking at two beaches: one covered with sand and another with large boulders. Both beaches could be of a similar size (scale) and shape but the texture or "grain" would be different. When assessing sustainability we need to consider the sources of data (and their reliability), the limitations to our understanding of how systems work, and our need for results that are meaningful. Not all information is meaningful (nor are data available) at the same grain. Some social information may be grouped by counties, some by communities, and some by certain social classes with little affinity for geographic boundaries.

An analytical modeling tool should be able to work with data and questions at multiple scales, based on different units and with different grains of focus or precision; it should also provide some means of resolving the differences between this multiscaled information. The ability to handle point and polygon data is highly desirable. The tool should also be compatible with existing geographic information systems (GIS) with respect to accessing and storing data as well as analysis and mapping.

Spatially Based Requirements of NetWeaver: The GeoNetWeaver Extension

In its original design NetWeaver was not a spatially based model. Although spatially based information could be incorporated into NetWeaver, multiscaled information from different units and grains of focus could not be easily incorporated; and the information could not be easily displayed spatially. Two NetWeaver program extensions have been designed to address this problem: the GeoNetWeaver extension developed for the LUCID Project and Ecosystem Management Decision Support (EMDS). Prior to the development of GeoNetWeaver, EMDS was evaluated as a potential tool. It had many desirable features in its current form it did not at that time meet the spatial requirements of the LUCID Project. The LUCID Project worked with the NetWeaver software authors to develop a spatial extension called GeoNetWeaver. This extension included a means of loading spatial data from multiple spatial layers and polygons into NetWeaver and analyzing and displaying the results at multiple scales. GeoNetWeaver was designed with an independent, stand-alone mapping program; and consequently, its display and mapping features are less enhanced than EMDS. Ultimately, a spatially based extension that combines the desirable features of both programs is preferable particularly in a format that works seamlessly with USDA Forest Service corporate GIS software.

Chapter 12 profiles some of the key features of GeoNetWeaver, including its ability to work with multiple polygon layers to provide a broad overview, with spatial variation, of the assessment of an indicator compared to its reference value, to display the results of the synthesis of evaluations at each level of the C&I hierarchy, to pinpoint areas for further analysis or examination, and to perform detailed analysis on specific geographic units (e.g., a watershed) (Figure 37).



Display of mapped results showing extent that a network meets references value.

Enables analysis of specific polygons to determine what is contributing to displayed values.

Results of polygon analysis displayed in the dependency network and in associated charts and graphs.

Criterion	Results	Data Sufficiency
I2.4 Water Quality	-0.845	67%

Figure 37. Spatially Based Features of GeoNetWeaver

Alternative Spatial Extensions to NetWeaver: The EMDS Program

Ecosystem Management Decision Support (EMDS) was designed for the USDA Forest Service and currently is managed as part of the NRIS tools system as an application framework for knowledge-based decision support of environmental assessments (Reynolds 1996). EMDS integrates the NetWeaver knowledge-base program with ARC GIS software. EMDS provides an excellent way to move relatively seamlessly between NetWeaver and the Forest Service corporate GIS software incorporating and displaying the results of NetWeaver analysis spatially. In its initial form EMDS required the user to choose a common set of spatial units *a priori* and attach all the data for each model component to those same spatial units. Although EMDS had many desirable features of converting an expert-based model to a spatially based model, the requirement to use a common set of polygons was viewed as a limitation on most of the LUCID forests.

The EMDS application of NetWeaver incorporates a feature called the Data Acquisition Manager (DAM) assessment subsystem. The DAM uses information about the influence of missing data plus information gathered from the user (in an interview dialogue) about the ease of acquiring missing data to prioritize missing data as an aid to planning new data collection to improve an assessment. A variety of maps, tables, and graphs provide useful information about what data are missing, the influence of missing data on completeness of the assessment, and how they are distributed in the landscape (http://www.fsl.orst.edu/emds/).

Caution must be used in interpreting the DAM results because the influence values are dependent on the location of a data element within the NetWeaver dependency network (the higher up in the network the more influence it has) and on the number of times a component is repeated within a network (the more times a component is used the more influence it has). This would give components higher in the network hierarchy and those repeated often more influence than singular components lower in the hierarchy; it does not necessarily follow that these higher level, repeating elements are more important to collect as missing data than are lower order, singular elements. More than just the structure of the NetWeaver dependency network needs to go into the decision on which missing data to collect.

A Range of Reference Values: Discrete and Fuzzy Reference Values

Reference values are the benchmarks, standards, thresholds, or desired system conditions against which measures are assessed and are the means of gauging the state of an indicator. Reference values (Chapter 10) can be set as either discrete (an absolute value or a range of values) or as fuzzy. Fuzzy values rely on a branch of applied mathematics called *fuzzy math* (see, for example, Kosko 1993) and is best described best by the phrase "true to the degree that." Fuzzy reference values interpret data for a measure against a reference value to the extent that it achieves the desired value.

The uncertainty associated with setting reference values and the inherent social values nature of sustainability make it rarely possible to identify discrete reference values. Consequently, a knowledge-based analytical tool incorporating fuzzy math for the calculation of reference values was desirable. Fuzzy set theory is particularly useful where the boundaries between judgments or values are not precisely known. Typically, the primary mathematical tool to deal with uncertainty has been probability theory; however, probability theory is less useful where the deterministic and dynamic relationships between all combinations of elements are unknown (Li 2001). Additionally, although the Bayesian mathematical approach to probability modeling can be used to address uncertainty it is uncertainty between a set of choices on probable outcomes and not for comparing a suite of measures against reference values. We were interested in a modeling approach that incorporated fuzzy set theory into the development of reference values rather than for assessing probability of various outcomes.

Fuzzy Logic and NetWeaver

NetWeaver is built around the mathematical concept of fuzzy logic and allows both fuzzy and discrete reference values to be used. The fuzzy reference value application allows degrees of attainment (or nonattainment) of a data reference value as opposed to a typical discrete or threshold standard that either is, or is not, attained. Very few of the data items the LUCID forest teams evaluated to gain insight into sustainability had hard and fast set bivalent standards, so the ability to evaluate degrees of attainment of a standard, benchmark, or reference condition was a desirable feature in a modeling program. Within NetWeaver the user sets upper and lower values (defining the 100 percent attainment and 100 percent nonattainment points) along with mid-points if a specifically shaped curve is desired then NetWeaver assigns values between these two conditions—allowing an assessment without forcing the determination of a threshold value. Data values anywhere on the attainment curve receive a value from –1 (100 percent nonattainment) to +1 (100 percent attainment) passing through a mid-point value of 0 that represents neither attainment nor non-attainment (Figure 38). The attainment/non-attainment can be examined spatially as depicted in the shades of red and green in Figure 37.

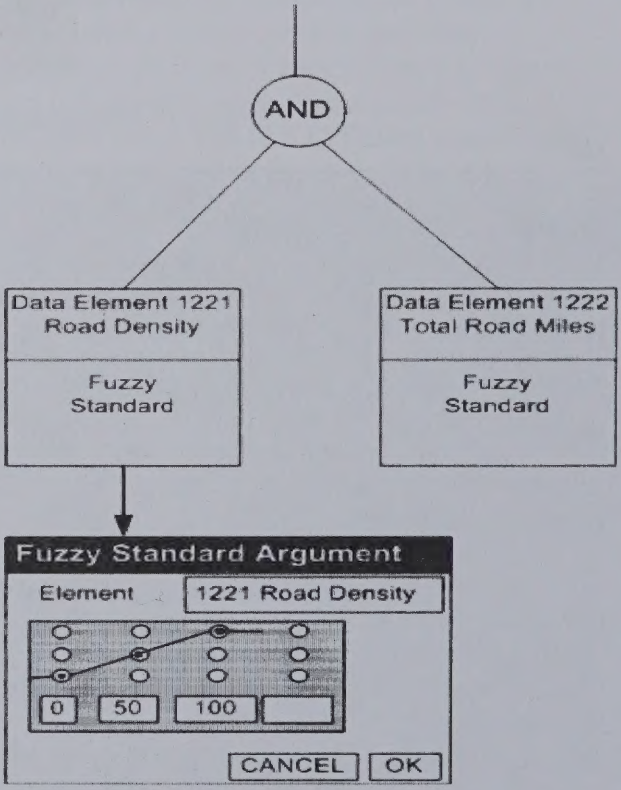


Figure 38. Fuzzy Reference Values

Weighting

Weighting is a means of identifying and determining the relative value of each element. Although there are important technical issues regarding weighting that are discussed below, the initial determination is a philosophical one. Do all elements have equal value? Are they all equally important? This decision-making process must be repeated at each stage of analysis.

There are two weighting issues that are important features for technical tools.

1. Intrinsic weighting is the inherent weighting that is associated with an analytical model and is based on the algorithms used to combine elements together. Intrinsic weighting should be logical, transparent, and unbiased.
2. Purposeful weighting is the ability to adjust the value of elements because of a conscious decision to give more weight to one value than another. Purposeful weighting should also be logical and transparent.

Both the algorithms used to combine elements together and specific weighting functions may be used to control weighting.

An Expert Approach to Weighting: Multi-Criteria Decision Making in Kalimantan

Weighting indicators to combine them in the construction of a sustainability index using Multi-Criteria Decision Making was one step in a CIFOR study of FMU-C&I in Kalimantan. Scientific experts were asked to conduct a pair-wise comparison of indicators to rank their relative importance. Consistency in the comparison rankings was checked by having the experts repeat the ranking process individually after discussions between the experts. An inconsistency index was calculated to inform subsequent rounds of ranking. Relative weights, along with an inconsistency index, were calculated based on these pair-wise assessments and used to inform the construction of a sustainability index.

(Mendoza et al. n.d.)

Weighting in NetWeaver

For the purposes of the LUCID Project, we based our initial approach on the assumption that each of the ecological, social, and economic systems (the principles and criteria) was critical for sustainability and that no one system component was more valuable than another. We recognized, however, that the decision about the relative value of components is critical and that the answer may be different from place to place or situation to situation. Consequently, within the LUCID Project we set about exploring the implications of our approach in terms of the implied intrinsic relative value of components and the strengths and weaknesses of tools and techniques to examine this.

Weighting within NetWeaver is affected not only by the algorithm used to combine elements together but also by a specific weighting function that allows the user to set a purposeful weight for an element. A brief summary of the findings are presented here; however, because this is a complex topic that was of great interest to the LUCID participants Appendix 14 provides a more detailed discussion of the basic weighting issues, the findings from the LUCID Project, and the possible solutions.

Intrinsic Weighting

With the analytical approach and technical tool we used for the analysis function, we were able to look at the actual contribution or importance of individual elements (e.g., data elements, indicators, criteria) and assess whether the hierarchical structure issues and the effect of an unequal distribution of elements within hierarchical layers had a significant effect.

Our conclusion during the LUCID forest tests was that given the large number of total elements in the forest team's suites of C&I, any one element had such a relatively small contribution to the total that while it was important to acknowledge that there was a difference in inherent relative contribution it was deemed negligible. Because most analysis was conducted within the same hierarchical level (e.g., all indicators together) and because we assumed that each and every element that was included was a critical element of equal importance, we did not attempt to develop a hierarchical model with the exact number of elements at each hierarchical level. If the suite of C&I to be analyzed was much smaller, then this unequal distribution of relative weights would be more important.

Purposeful Weighting

During the LUCID Project, forest teams were encouraged not to use the weighting function. This was particularly the case since the forest teams used the fuzzy math algorithm (the "AND" algorithm) almost exclusively throughout the hierarchy (see sidebar box). The combination of the fuzzy math and weighting algorithm added a level of complexity and subjectivity that we were not prepared to address during the test process.

As the forest teams began their testing process, they began to challenge the original assumptions that each item at a hierarchical level had equal value and that the conditions for each must at least be partially met. The key questions that resulted were:

- Within a systems context are all elements (e.g., criteria) preconditions for sustainability?
- Are all elements equal to one another?
- Must the conditions for each element be met at least partially?
- Is a precautionary or conservative approach useful and if so, when?

Upon completion of the selection of the monitoring elements and the initial analysis, a number of forest teams concluded that not all of the elements that they included in their lists of C&I necessarily had equal value and that they thought that weighting should be a viable option. This was particularly true at the lower levels of the C&I hierarchy (e.g., measures and data elements). One of several measures for a select indicator may be identified as the most important measure and others may have less importance. Enabling condition or management process measures were often viewed as important but perhaps not as important as other measures. Similarly, where forest teams had less confidence in the accuracy or reliability of a certain measure or its associated data or reference value, they often indicated that they felt it was important but perhaps less important than other measures. This was frequently the case when a proxy measure was used.

Aggregation Algorithms Within NetWeaver

As a hierarchical, object-oriented, knowledge-based model, NetWeaver can combine model components and elements in a variety of ways for synthesis and aggregation. Data values are compared against reference values and normalized on an attainment scale of -1 to +1. Data elements within dependency networks are joined together with a logical statement or "operator" based on the purpose of the dependency network and the desired meaning for synthesis and analysis.

The *AND* operator is based on the premise that the proposition depends on component *X AND* component *Y;* and if one component is completely untrue then the proposition is not met. When the normalized values of data elements are combined with an *AND* node, it is based on a conservatively weighted fuzzy mathematical algorithm. Values are weighted more to the negative than to the positive; in other words, components with negative values have greater influence within the *AND* operator than do components with positive values, and the more negative a component is the more influence it has on the fuzzy *AND* calculation. This conservative nature of the fuzzy math calculations within NetWeaver prevents over-achievement of the goals within the dependency network that are connected by *AND* operators.

Alternatively, a *UNION* operator can be used that averages the values for all of the components in the dependency network. In contrast, a *SUM* operator adds the values for all of the components in the dependency network. In contrast to the *AND* operator, under these operators a negative component has no more intrinsic weight than a positive component (in the absence of explicit weighting), thus the calculated value at these operators is far less conservative than described above. This could potentially lead to a false over-achievement of the goals connected by the *UNION* and *SUM* operators.

The principles, criteria, indicators, and measures defined the basic hierarchical structure of the LUCID knowledge basis. Results could be interpreted individually at the lowest level of the hierarchy (e.g., measures) or the aggregated results synthesized at higher levels of the hierarchy where there was theoretical justification to do so.

In response the core team worked with the NetWeaver authors to develop alternative algorithms for synthesizing the results (see sidebar box on page 214). The relative effect of these different algorithms on weighting were modeled using data from the forests to examine the implications.

The core team concluded that if the aggregation algorithm was changed from a fuzzy algorithm to an averaging algorithm then the use of weighting as a tool was relatively straightforward and much more feasible (this approach results in the same algorithm used in Mendoza et al. n.d.).

After a review of the initial project assumptions and based on the comparative analysis of the different approaches, the core team recommends the following responses to the questions above:

- The systems framework is based on the premise that the criteria represent fundamental system components and processes, each of which is critical for sustainability. Additionally, a conservative, precautionary approach seems most applicable. Consequently at principle and criterion levels weighting is not recommended and the fuzzy math (AND) aggregating algorithm seems most appropriate.
- The selection of the indicators is predicated on a "critical" indicators approach that attempts to get at a parsimonious set of the most important indicators. Consequently weighting at the indicator level of the C&I hierarchy is not recommended. Similarly, the fuzzy math aggregation algorithm (AND) seems most applicable.
- At the lower levels of the hierarchy (data elements and measures), the comparison against the reference value should result in a full range of possible assessments from –1 to +1. The interdisciplinary team should evaluate *a priori* whether the failure for an element to meet the reference value even partially (a –1 value) a) can be offset by other elements, in which case a UNION or SUM algorithm should be used or b) whether each element is of critical importance and the conditions for it must be met at least partially, in which case the fuzzy math AND algorithm is appropriate. The choice of the appropriate algorithm should be made on a case-by-case basis and is dependent on the types of elements (e.g., measures), the nature of the data, and an assessment of the importance of each item.
- Weighting may be a very desirable option at the lower levels of the hierarchy (measures and data elements) but should be used cautiously and the mathematical implications modeled if the aggregating algorithm is the fuzzy logic "AND" node.
- A consistent approach should be used from forest to forest in determining the appropriate use of weighting and the aggregating algorithms at each hierarchical level.

Incomplete Models and Missing Data

It is highly likely that a model built to represent a topic as complex and values-oriented as sustainability will ever be complete and likewise obtaining complete information for all elements and for all areas of interest is highly unlikely. Any technical modeling tool should be able to both function in the absence of a full complement of data and also provide an assessment of the extent or impact of missing data.

Treatment of Missing Data in NetWeaver

The modeling engine of NetWeaver has several features that relate to missing data. In its simplest form, the evaluation of a network shows not only the reference value (represented as 100 percent positive or negative) but also a data sufficiency value. The data sufficiency value is a percentage calculation of the extent to which there is a complete set of data and reference values for the components of the dependency network. Where all data elements are populated and reference values have been set, the data sufficiency value will be 100 percent.

The default setting for dealing with missing data/missing reference value is that the data element evaluates to a value of 0. The assignment of the 0 value for missing data implies that the data element has a neutral impact on the overall analysis, however, given the conservative mathematics of fuzzy logic in the synthesis function values less than +1 carry an increasingly greater influence. Consequently, the default treatment of missing data typically will result in a more conservative value in the synthesi, with missing data having a greater influence than components with positive data values. LUCID participants expressed some concern regarding the difficulty in differentiating between a reference value score of 0 resulting from either missing data or from a true 0 calculation (when data are evaluated against a reference value and evaluates to the 0 point on the –1 to +1 scale). Ultimately, some means of differentiating between the two at least graphically may be desirable.

The user currently has the option of either temporarily (for that analysis only) or permanently detaching an element or a network from the analysis, and this may be a potential way to deal with missing data. The user may decide to detach data elements that have missing data or reference values (although elements may be detached for a variety of reasons) in order to do an analysis. Users should be cautioned, however, that the resulting values are likely to be overly optimistic; and if significant quantities of data or significant data elements are not populated they are discounted if this feature is used. This method of conducting an analysis is not suggested as the ultimate solution because it is extremely difficult in such an approach to infer what is not known about the data that might be relevant and how influential it might be for determining system conditions. A comparative analysis with and without missing data may be a useful step.

In addition to those features outlined above, the GeoNetWeaver provides additional graphical means of examining missing data (see Figure 39). Data sufficiency values can be graphed and mapped for any data element or network and can be displayed as a screen on top of the derived NetWeaver values for that element/network so that the value and the extent to which there is missing data are presented simultaneously.

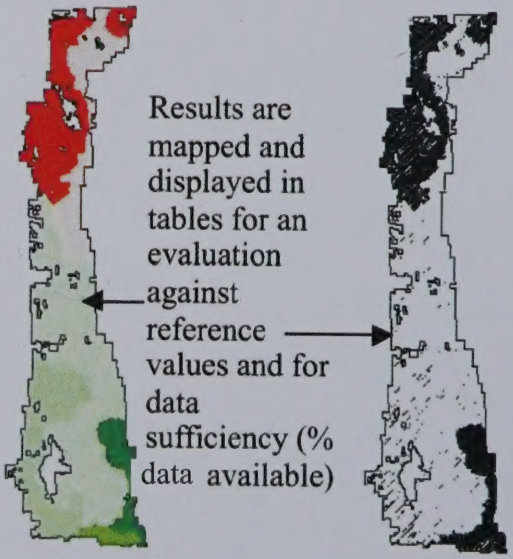

Results are mapped and displayed in tables for an evaluation against reference values and for data sufficiency (% data available)

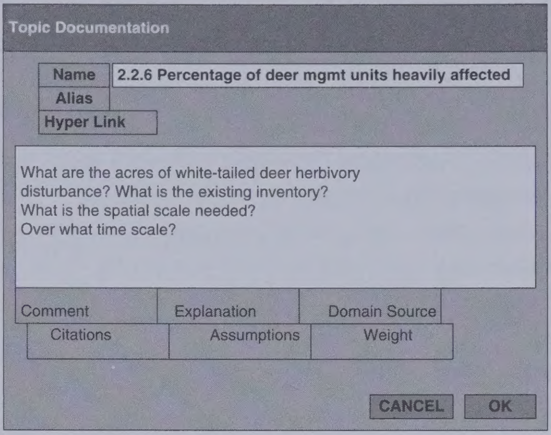
Figure 39. Data Sufficiency

> *Modoc National Forest: Clarifying data limitations*
>
> *"We feel that the model that we built during the course of this test is very much a prototype model, and cannot be used yet to draw very good conclusions about 'sustainability.' There are several reasons for this:*
>
> *There is a significant lack of data in our model, in the following areas: almost all of the areas outside the national forests boundary in ecological, social, economic systems; and lack of social data in general. This is not an unusual condition as measures pertaining to social attributes have not been a traditional Forest Service focus, so there is not a legacy of data to reference nor is there much in the way of readily accessible 'expert opinion.' The main reasons for lack of data are: they don't exist, no time to collect, or were considered such poor quality that we didn't use them. Blank data items in the model will skew results. The model converts blanks to zeros as a default, which can be a difficulty: This is because "zero" is a number with value and is used in calculations by the model. If there is a great deal of missing data and a few items that do have data, the score for that item will be modified by including numerous zeros rather than calculating the score based on the populated part of the database. This can be very misleading in our view, and changing this default should be an option in the software."*
> *(Modoc National Forest Team)*

Transparency and Documentation

Prabhu et al. (1999) note the importance of transparency in analytical tools. Although transparency and thorough documentation of assumptions is a desirable attribute of any analytical tool, it is particularly the case with sustainability modeling because the evaluations depend largely on social choices based on a series of critical assumptions. The relative arrangement of components in the model, the reference values, and the synthesis and aggregation protocols require careful documentation.

> *"If a picture is worth 1,000 words, then the NetWeaver specification for evaluating sustainable forest management is worth about 225,000 words. Although the persistent form of the meta data is scored as an ASCII file that only a software engineer could love, the logic engine constructs a graphic representation of each topic "on the fly" during design and evaluation of a logic model. The graphic form of logic representation is significant because, based on extensive experience, the semantics of any particular model are easily conveyed to broad audiences in this form. Consequently, a group of specialists, representing diverse disciplines, can easily collaborate in the design of a complex model because the architecture and its graphic representation provide an effective basis for organizing discussion and for continuing evolution of a design."*
> *(Reynolds et al. 2001)*



Name: 2.2.6 Percentage of deer mgmt units heavily affected

What are the acres of white-tailed deer herbivory disturbance? What is the existing inventory?
What is the spatial scale needed?
Over what time scale?

Figure 40. Meta-Data Documentation Form within NetWeaver

Transparency and NetWeaver

LUCID participants noted that they were concerned about imposing a potential "black-box" model into forest management. The knowledge-based approach of building the initial dependency networks and the graphic interface that conveys these networks and their organization are the key feature of aiding transparency. Additionally, there is a detailed meta-data format with topics including citations, assumptions, and explanations for each component in the model (Figure 40). A number of forest teams used this documentation function to track the question of focus as well as assumptions. Other teams noted that with additional improvements to the import/export functions of the documentation tool the NetWeaver meta-data would be even more useful.

Some areas of the tool did require further explanation and documentation in order for transparency to be improved. The weighting function and the mathematical calculations of the synthesis/aggregation function (particularly those involving fuzzy math) were more difficult for users to understand; and although reference material was available in the help menu, LUCID users indicated the desire for additional material. Transparency may be aided by the ability to more clearly track the resulting mathematical calculations for each specific node. Distinguishing between missing data (0 values) and true data values that are assessed to a neutral (0) value was also an area for suggested improvement.

Interactive and Adaptable

One of the potential uses for an analytical modeling tool is the ability to use it inter-actively working with groups of technical experts or collaborators to run a series of "what-if" scenarios. Analytical tools that require a great deal of programming, require a highly technical operator, need background analysis, or have a cumbersome user interface are less useful in an interactive format.

Real-Time Modeling and NetWeaver

NetWeaver is a relatively interactive and adaptable analytical model. The object-oriented aspect of the model allows the user to select and build new dependency networks quickly. The spatially based analysis interface of GeoNetWeaver facilitates quick processing of the entire study area or the selection of only specific coverages (map layers) or points/polygons for analysis. Navigation between the elemental data, the dependency network itself, the mapped output along with associated charts and figures, and the meta-data is seamless. Two key features of NetWeaver that rank highly in this regard are 1) the ability to input multiple reference values either in advance or on the fly in order to perform alternative analysis scenarios; and 2) the ability to change the actual input data value (although the original data base is not changed) to experiment with the sensitivity of the evaluation to different data.

In LUCID test applications real-time modifications were made to the model with a group of experts to examine either a subset of components, to experiment with different reference values, and to run what-if scenarios based on changing data values (Figure 41). In most cases the feedback was instantaneous although those forest teams with more complex supporting GIS mapped layers did find that in some cases the processing time made interactive use less feasible (technical solutions for this challenge are possible, however). Forest teams indicated that overall the interactive and flexible nature of the tool made it very desirable, and they anticipated that one of the strongest potential uses was in an interactive application with forest managers and with collaborators exploring a variety of different scenarios. The adaptable nature of NetWeaver is aided by the fact that it is highly graphical in orientation and output (in particular the mapped GeoNetWeaver output). Consequently, it is easy for non-technical personnel to follow along.

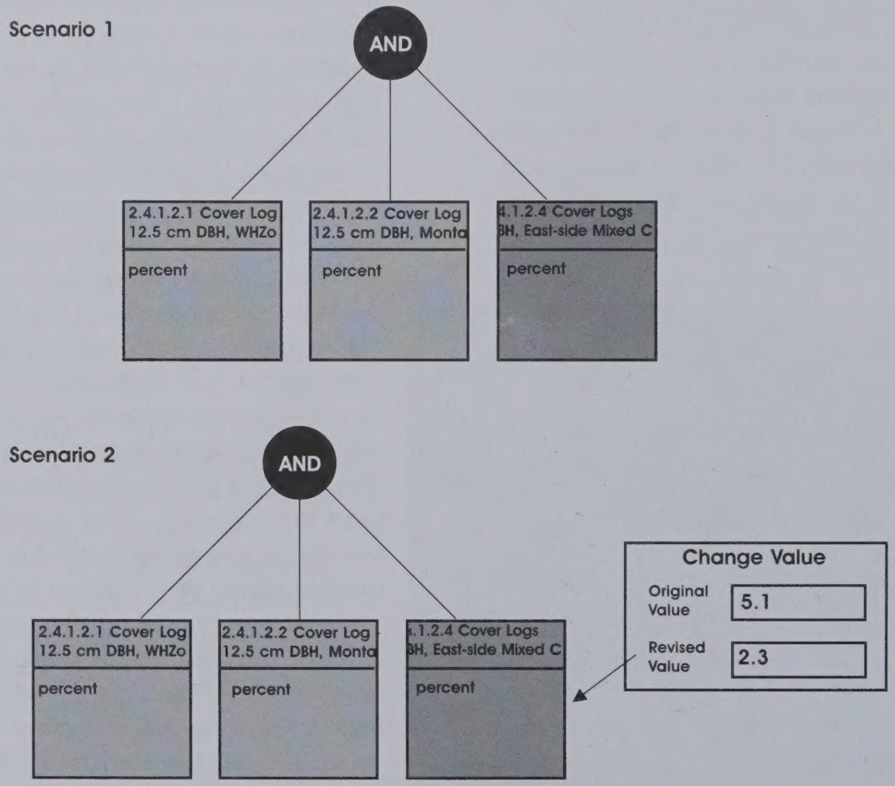

Scenario 1
AND
2.4.1.2.1 Cover Log 12.5 cm DBH, WHZo
percent
2.4.1.2.2 Cover Log 12.5 cm DBH, Monta
percent
4.1.2.4 Cover Logs BH, East-side Mixed C
percent
Scenario 2
AND
2.4.1.2.1 Cover Log 12.5 cm DBH, WHZo
percent
2.4.1.2.2 Cover Log 12.5 cm DBH, Monta
percent
.1.2.4 Cover Logs BH, East-side Mixed C
percent
Change Value
Original Value
5.1
Revised Value
2.3

Figure 41. What-if Scenario Modeling

Compatibility

To be useful for application to sustainability monitoring and within the operating arena of the Forest Service, an analytical modeling tool should be flexible, user friendly, and transparent. Analytical tools should be compatible with existing USDA Forest Service corporate systems including data management (e.g., import and export capabilities with existing corporate software) and geographic information systems.

NetWeaver and GeoNetWeaver Compatibility with Forest Service Systems

The GeoNetWeaver software was developed to run on an independent personal computer platform using ArcView shapefiles and database files for data inputs. The software provides the ability to graphically create, manipulate, display, and analyze a complex dependency network. The use of GIS functionality allows the results of the network analysis to be displayed spatially. As a stand-alone application, GeoNetWeaver operates independently of the corporate Forest Service networks, software, and data structures. This design made a lot of sense to the developer because he could not assume that all his customers will possess the kind of integrated corporate computing platforms found within the Forest Service.

To maintain portability, the GeoNetWeaver software used PC ArcView and Map Objects to perform GIS Union and Intersect functions. This stand-alone architecture created data processing inefficiencies when large, complex polygon data sets were used. It would be more efficient to use the processing power of ArcInfo when performing topological overlays in support of FMU-scale sustainability analyses.

The functionality provided by the integration of network analysis and spatial display is very valuable. This software provides access to "what if" capability that planners have been seeking. Consequently, the utility of the tool may extend well beyond sustainability modeling. In their current form, however, there are needed improvements to NetWeaver and GeoNetWeaver to make them more functional within a Forest Service environment.

Corporate Software

The functionality of NetWeaver and GeoNetWeaver should be accessible through the corporate software suite. One of the exciting advantages to the software is its spatial display capability. Both the GeoNetWeaver and EMDS extensions have a variety of highly desirable features; but as yet, neither tool contains all of the desired features. Currently, EMDS is being incorporated into the Forest Service corporate approach as part of the NRIS tools program, which is part of the Arc GIS software. The desirable features of both GeoNetWeaver and EMDS should be made accessible in some fashion to Forest Service users.

User Data Interface

The LUCID Project revealed the need for a standard user data manipulation interface. There are many potential solutions to this problem. Spreadsheets were the most commonly used method for entering data into DBF files. Spreadsheets provided an easy user interface for data entry and were easily operated by resource specialists, some of whom were unfamiliar with more technical solutions to data entry. Spreadsheets presented some difficulties as team members spend considerable time rectifying problems with spreadsheet data entry. To be used in the Netweaver model spreadsheets had to be converted to DBF files, maintain linking fields, and adhere to field naming rules. On several occasions, users attempted to edit SHAPEFILE DBF files within a spreadsheet environment. This resulted in shapefile corruption.

Multicriteria Decisionmaking (MCDM) and Sustainability Monitoring

The desire to synthesize the results of sustainability monitoring in ways that integrate results and reduce complexity in meaningful ways and express it in a spatial format led researchers working with the Center for International Forestry Research (CIFOR) to investigate the application of multicriteria analysis to FMU-scale C&I (Mendoza et al. n.d.).

MCDM represents a set of tools typically used in situations with several options or alternatives such that each alternative results in a different level of achievement relative to the overall objective. In the context of C&I, the authors describe MCDM as "structured in a hierarchical framework so that objectives are represented by the higher level hierarchy while the options or alternatives are represented by lower level hierarchies." The focus is not on optimizing the choice between alternatives but rather trying to determine what the "combined effects of each option (e.g., indicator) at each level in the C&I hierarchy" are. MCDM in this context can be used to help estimate the overall measure of sustainability at the top of the hierarchy (a sustainability index) as well as to "determine the individual importance, effects, or impacts of each element at the lower levels of the hierarchy," producing an estimate of the effect or relative impact to sustainability of each element in the lower hierarchy.

The researchers employed a particular MDCM approach that involved four broad steps: 1) design a decision hierarchy based on the sustainability C&I hierarchy; 2) using expert comparative judgments, conduct pair-wise comparisons of the importance of each element in the decision hierarchy; 3) synthesize the judgments to estimate the relative weights of importance for each element; and 4) determine the aggregate relative weights of the elements.

Data (both quantitative and qualitative) for the verifiers associated with each indicator were assessed against reference values and analyzed based on the aggregated relative weights in the decision hierarchy. The application of MCDM that was tested incorporated both fuzzy logic in the formation of reference values and a spatial dimension to the display and analysis of results. Reference values were set for each measure based on fuzzy set theory "since it is highly unlikely that precise estimates can be made on the sustainability of forests, it is more meaningful to characterize assessments not in terms of whether forests are sustainable or not. Instead, it is more appropriate to characterize assessments in terms of degrees of sustainability" (Mendoza et al. n.d.). The results of individual verifier assessments were combined into an overall sustainability index for each dimension or criterion.

In a test application of FMU-level C&I for Kalimantan, Indonesia, the sustainability index for the biodiversity criterion was applied spatially using ArcView GIS software (Figure 42). Data for verifiers were collected spatially and mapped and the indicator evaluations mapped. An aggregate sustainability index was generated by producing a composite map in ArcView that was based on an aggregation algorithm of a weighted average of the results of each verifiers evaluation.

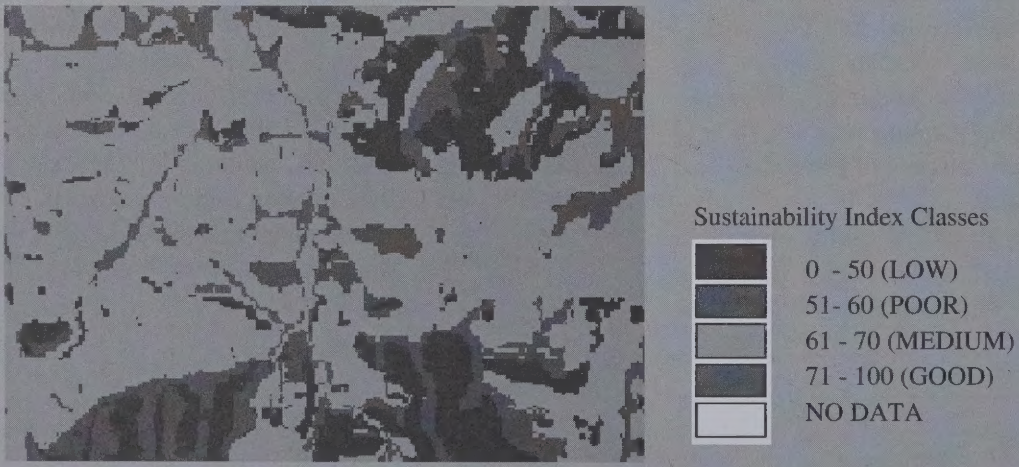


Figure 42. Classification of Sustainability Index

Synthesis and Integration Issues

One of the key desired attributes for an analytical modeling tool is the ability to synthesize and integrate information from component to component. There are two fundamental components to the topic of synthesis. The first, dealt with in this section, relates to the merits and possible approaches to synthesize the results of individual indicator analysis to help say something more about the state of the whole system. The second component relates to the potential for using the information attained from FMU-scale sustainability monitoring to contribute to our questions and study of sustainability at other scales. Although aspects of this second component are alluded to here, they are more fully developed in Chapter 14. In this section the value and challenges of synthesis are discussed followed by an overview of some of the possible approaches and implications for technical tools.

The idea of synthesizing or aggregating indicator monitoring information is inherently appealing. Generally, synthesis and aggregation are pursued to reduce complexity, to facilitate comparisons, or to understand some higher order synthetic concept.

Reducing Complexity

Reducing complexity is a primary driver for exploring synthesis and aggregation techniques and particularly desirable for improving communications and decision-making and for making comparisons from place to place. The basis and techniques are relatively uncomplicated if the items have the same units and can be synthesized across topic, spatial and temporal scale, and still have meaning. The desire to combine to reduce complexity is also the weakness: aggregation results in a loss of detail. Grade point averages (GPA) synthesize individual grades into one index. GPA is generally accepted and quite useful for making comparisons among students or giving a general indication of performance. However, examining the GPA of an individual student doesn't provide information on individual areas of strength or weaknesses. Many people have also questioned the theoretical underpinnings for GPAs. Some academic institutions or employers use the GPA index as a synthetic value representing base intelligence or potential. The extent to which academic classroom performance in a specific context-controlled environment within a limited set of topic areas over a specific period of time can be used to predict intelligence or potential is the subject of much theoretical challenge. Reducing complexity through aggregation may still be desirable, but the GPA example highlights the importance of determining whether or not the units to be combined should be combined.

Facilitating Comparisons

Allocation of scarce resources and evaluation of progress can be aided by tools and techniques to compare one object or place to another. Synthesis and aggregation can also be used to help facilitate comparisons from one place to another. Continuing with the GPA example from above, the merits of comparison depend on an understanding of whether things can be compared and how meaningful that comparison will be. Comparison of GPA between students is very common. The more the student's context varies, however, the less meaning there is to the value of the GPA in a comparative basis. Students from different economic backgrounds, students with different learning styles, students from different schools, students with different family values, support, or background in education have very different contexts each of which has a significant affect on the students' GPAs. The more there are variations in the contexts between students the less comparable GPA scores truly are.

A common set of criteria and indicators and mechanisms for monitoring sustainability can be very useful in order that there be a common means of framing our understanding of sustainability and for reporting, internally and to the public. Because the unique ecological, social, and economic contexts of each forest control the outcome of the evaluation of the indicators, synthesizing results to facilitate direct comparisons of the state of sustainability from forest to forest seems to have little value.

Synthesizing Concepts

If we know that sustainability is an inherently synthetic idea, then our journey involves not just identifying the individual components to monitor but in

> *"Connecting indicators will not be a simple task because physical and social systems often act differently at different scales." (Farrell and Hart 1998)*

understanding what this monitoring information means. How the components interact across time and space and what they can collectively tell us about the complex idea of sustainability are key concerns.

The exploration of the merits and methods for synthesis and aggregation depend in large part with the framework used to understand, select, and organize monitoring elements. The decision to pursue approaches for synthesis and aggregation relies on the theoretical assumption that there is something more to sustainability than the list of components. In this context the selection of components is based on some kind of conceptual model on how the components interact as the individual components (measures or indicators) are meant to be indicative of something larger.

In many sustainability-monitoring initiatives, the monitoring elements (C&I) are not selected on the basis of some theoretical relationship between components but rather to represent a range of important issues, objectives, or topics. Synthesis or aggregation in these scenarios will have a different purpose with different implications and may focus more on reducing complexity.

Alternative Approaches and Tools for Synthesis and Aggregation

Analytical models with synthesis and integration attributes are quite scarce, particularly in monitoring and sustainability applications. Most sustainability and C&I monitoring programs present the results of indicator monitoring on an indicator-by-indicator basis. The Dashboard of Sustainability program is based on a preset suite of sustainability indicators and data for 45 countries with a simple graphical display using indicators displayed on "dials" similar to a car or airplane dashboard (International Institute for Sustainable Development 2002) (Figure 43).

The construction of composite indexes (indices) of indicator evaluations is probably the most common means of synthesizing indicator information. The Barometer of Sustainability (Prescott-Allen 1997) integrates indicator evaluations into two indices: an index of human well-being and an index of ecosystem well-being (Figure 44). The numeric values of the two indices are combined on two axes graphically in a performance scale providing an assessment of overall well-being and progress towards sustainability. "The separation of human and ecosystem well-being ensures that an improvement in human well-being does not mask a decline in ecosystem well-being, or vice versa," such that a lower score on one axis does not override a higher score on the other (Prescott-Allen 1997). Meaningful techniques to convert indicator results to the scale have not been provided, however.

Although indices appear to be a straightforward and user-friendly way of presenting complex information the construction of meaningful indices is very difficult. As Farrell and Hart (1998) note, "connecting indicators will not be a simple task because physical and social systems often act differently at different scales."

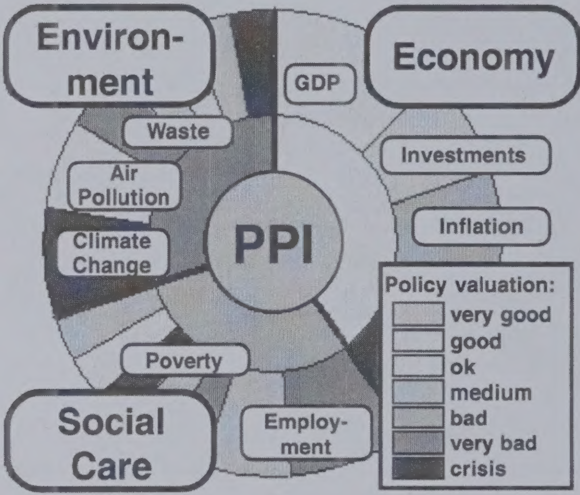


Figure 43. Dashboard of Sustainability

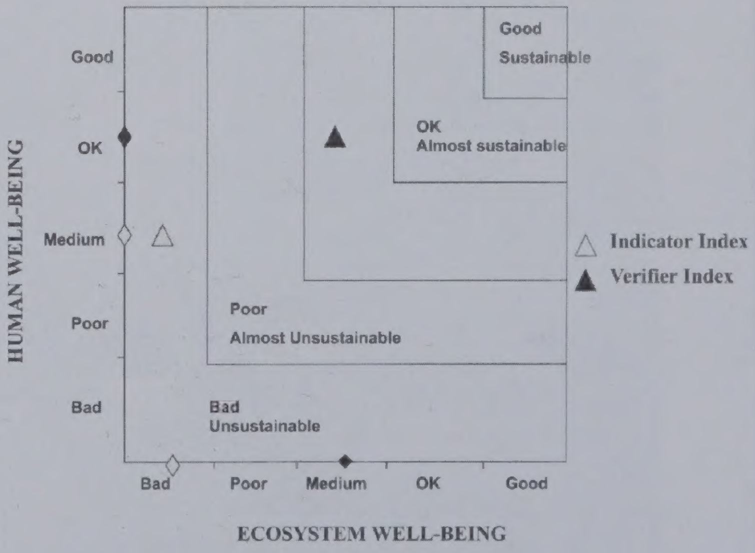


Figure 44. Barometer of Sustainability

Combining networked indicators through Bayesian probability statistics has also been applied to monitoring and resource management decision-making. IDRISI software combines Bayesian decision-support systems with the spatially based attributes of IDRISI GIS (Clark Labs). Although probability statistics are useful for elaborating components of sustainability, they require the user to know the extent and direction of the interactions between all components and then, typically through professional assessment, assign a probability that a particular outcome will result. As noted in the fuzzy math section above, probability theory is less useful where the deterministic and dynamic relationships between all combinations of elements are unknown (Li 2001).

Alternatively, Alces (Forem Technologies Ltd. 2001) program uses STELLA modeling software as the driver and constructs neural nets of indicators.

Optimal features of the synthesis/integration function of an analytical model include:

- Analysis both at the level of the individual indicator or measure and at higher levels of the hierarchy;
- The ability to combine indicator information in a variety of ways based on logic models;
- The ability to work with spatial data and spatial variation of analysis across multiple scales;
- The incorporation of fuzzy and discrete reference values;
- Adaptability to work with incomplete information;
- Interactive and adaptable tool; and
- Transparency.

Aggregation in What Form: Narrative or Numbers

The synthesis and aggregation of results can be presented in a variety of ways. Numeric approaches can provide a simple, compact, and easily comparable way to aggregate results but can be very controversial because the composite number or index presents a simplified view of a complex phenomena. Consequently, the aggregation algorithm must be meaningful, understandable, and have the assumptions stated clearly.

Alternatively, results can be synthesized in a narrative form. Narrative presentation of the results can convey the interactions between components while telling the story of sustainability that interprets the results in light of the specific contexts that affect the outcomes. The more complex the scenario the more likely a narrative-based synthesis will be the most informative.

Synthesis and Integration within the LUCID Project

The systems framework combined with the hierarchical tools of criteria and indicators helped in the development of a suite of C&I for FMU-scale sustainability monitoring. However, the development of the C&I was only the first phase of the LUCID Project. The hierarchical organization of the principles, criteria, indicators, measures, data elements, and reference values developed in the context of this systems framework stresses the need not just for examination of an individual data element for a select indicator but also in the value and need for synthesis of the results of the information.

The LUCID forest teams and the LUCID core team experimented with a range of possible approaches to synthesis and aggregation of results including the detailed investigation of the NetWeaver and GeoNetWeaver technical tools. This section presents a summary of some of the issues and experiences of the forest teams.

Reducing Complexity

Within the LUCID suite of C&I, the indicators vary across scale, time frame, and topic such that aggregating the results into a composite index is not theoretically sound. Within the suite of indicators, however, there are measures or groups of measures for which synthesis into an index can be useful and indeed provide more meaningful results than examination of the individual components. The Index of Biotic Integrity (IBI), for example, combines a suite of individual data element measures into an overall assessment of the health and functioning of aquatic systems. Not only is complexity reduced by using this index, but the results are much more meaningful.

Synthesizing Concepts

The premise of the LUCID Project was that sustainability emerges from the interactions and maintenance of the fundamental structures and functions of ecological, social, and economic systems. Indicators and their associated measures and data elements were developed within a systems framework on the basis that they were indicative of some critical systems component. Consequently, the ability to synthesize the results of individual measures into higher order groupings required the resolution of a number of issues:

- A conceptual framework to represent the systems structures and functions and to associate and link between model elements;
- An appropriate sampling strategy and means of associating the data only with the places where those data values could be applied;
- A mechanism to associate data with the spatial units that they applied to and to reconcile evaluations across a range of different spatial layers;
- A means of normalizing the different values and units for each data element; and
- A range of aggregation algorithms to combine components according to the meaning implied in the conceptual framework.

Highlighting Areas of Concern

> *"This model helps isolate those places and identifies those actions that may be deemed a threat to sustainability or in dire contradiction to appropriate resource management policy."*
> *(Tongass National Forest Team)*

LUCID forest teams reported that one of the primary benefits of synthesizing and aggregating results was to "flag areas of concern" for further analysis. The NetWeaver/GeoNetWeaver tools allowed areas of concern to be highlighted by element (e.g., indicator or measure) or by spatial area. Forest teams noted that aggregating results at the upper levels of the hierarchy was most useful to signal areas that need to be probed in more detail.

Pursuing Interrelationships

> *"The real value of the measurement side of GeoNetWeaver is to provide a safety net evaluation of vital signs across the primary components of the social, ecological, and economic systems. It will also serve to highlight elements doing quite well and reveal trends over the long-term to provide helpful predictive feedback to managers and interested publics."*
> *(Allegheny National Forest Team)*

Measures and indicators were selected and organized within a systems framework; and therefore, synthesizing results by system or system component was beneficial because it provided an overview of the state of the system. Still, many LUCID participants expressed a desire for a more predictive approach to analysis that would model the interactions between the elements such that the cascading effects of the evaluation of one indicator would be traced to related indicators. Although the tool has the capability through the use of calculated data links and mathematical expressions to perform some of these functions, some LUCID participants had expectations that mathematical expressions of relationship between elements would be automatically generated. In this way they found the tool lacking, noting that its "unidirectional hierarchy does not show the many interrelationships between elements in the model" and consequently it "does not address cumulative effects" (Blue Mountains Province Team). However, most participants recognized that setting up a directional and predictive model would be extremely difficult and well beyond our current level of understanding.

Issue Analysis

One feature that forest teams did find useful was the ability to use the same material to pursue analysis of specific subissues (either by topic or spatially). After experimenting with the various possible approaches for sub-issue analysis and the potential strengths and weaknesses of them, most participants concluded, that the value of the tool lay in the ability to quickly select a sub-set of components (e.g., measures or indicators) to examine a specific issue. However, attempting to numerically synthesize the results in new hierarchical arrangements in absence of the systems contexts the elements were associated with was judged to be problematic.

"Suppose one pulls out all of the data items pertaining to an issue like grazing. Potentially, this has a lot of value, to look at an issue in an integrated way. However, when we do this what is the effect… Are we truly measuring the sustainability of the issue, or are we skewing results by picking select elements from the big model?"
(Modoc National Forest Team)

Spatial Display

A key feature of the modeling tools was the ability in GeoNetWeaver to analyze sustainability across various spatial scales or extents. forest teams noted that the spatial feature gave a comprehensive view of forest issues and spatially displayed problem areas and areas with good conditions.

"The visual display capabilities of the LUCID monitoring (GeoNetweaver) are recognized as potentially very effective. The spatial displays help greatly as people tend to relate to 'place' while exploring issues and outcomes. Being able to display linkages helps illustrate the complexity of relatedness of many measures or issues."
(Modoc National Forest Team)

IMPLICATIONS

The application of analytical tools to sustainability monitoring is very limited and thus the work of the LUCID Project involved a great deal of exploration of possible techniques and tools from a limited set of resources. The forest teams became actively involved in developing and designing technical computer-based tools to evaluate them for potential application to assist in the sustainability assessment process. At times the development and testing of these tools threatened to overwhelm the larger project. Given that the LUCID participants were so actively involved, the domination of the tools is not surprising and to great extent is probably unique to the testing circumstances. However, the potential for any tool or program to dominate is an important caution that should be considered during implementation. In the end no one tool will be able to accomplish all tasks and caution should be taken in selecting and using any technical tool.

While development and enhancement to address some of the limitations is still needed, in the end we found that the NetWeaver tool had more of the desirable features we were looking for than other tools we examined. A spatial extension, both to organize and input data as well as to display and analyze it is highly desirable. Here there are currently two options that work with NetWeaver: Ecosystem Management Decision Support (USDA Forest Service 1998a) and GeoNetWeaver (Rules of Thumb, Inc. 2002). At the time of our evaluation, both had unique and very useful features but neither had all of them. One program that had all features would be highly desirable.

Is it possible to conduct a sustainability assessment without the use of technical modeling tools?

To date, the overwhelming majority of C&I applications have focused on indicator-based analysis and reporting that has required no more than readily available data analysis tools (e.g., spreadsheets or statistical software) and display techniques, including GIS software and charting software.

Most other initiatives that have sought to synthesize the information from individual indicator assessments have typically used these same techniques to provide present the complexity of information in summary forms. The report card format illustrated by the Oregon Benchmarks program (see Figure 45) is one common approach. Others promote the use of novel display techniques (see Figure 43) to present the results of single or aggregate indicator indices.

Given the set of tasks involved in sustainability assessments and the myriad of relationships between indicators and data, without technical tools the user can get overwhelmed in organizational chaos and attempts at synthesis can be confusing.

Within the LUCID Project we were interested in exploring the utility of tools that allowed us to not only summarize information and display it in useful ways but also to provide us with analytical

[illegible]	1998	2000	Page
KEY ENVIRONMENT BENCHMARKS			
Air Quality	A	A	63
Land Prevervation **Wetlands, Agricultural and Forest Lands**	A	B-	64
Salmon & Steelhead	F	F	67
OTHER ENVIRONMENT BENCHMARKS			
Carbon Dioxide Emmissions	**F**	**F**	**68**
Stream Water Quality	**A**	**B+**	**68**
Instream Water Rights	**A**	**A**	**68**
Timber Harvest		*new*	*69*
Municipal Waste Disposal per Capita	**F**	**F**	**69**
Hazardous Waste Site Clean-up	**A**	**A**	**60**
Heathly Wildlife Species	**F**	**D-**	**70**
Marine Species at Risk		*new*	*70*
Healthy Native Plant Species	**C-**	**D-**	**70**
Nuisance Species		*new*	*71*
State Park Acreage	**F**	**F**	**71**
AVERAGE OTHER GRADE	**C+**	**C-**	
OVERALL ENVIRONMENT GRADE*	**C+**	**C+**	

Figure 45. Oregon Benchmarks Report Card

tools that allowed us to synthesize information in a way that was consistent with our understanding (our conceptual models) of the nature of systems.

Do we need one tool that will perform all of the functions?

The CIFOR approach using Multi-Criteria Decision Making (Mendoza et al. n.d.) or the Sustainable Communities Indicator Program (Government of Canada 1998) combined a variety of existing tools to achieve some of the functions (including spatial display abilities, fuzzy reference values, and for the MCDM program an aggregation capability) that were highlighted in this chapter.

If we can achieve the various functions in a relatively seamless fashion without incompatibility problems or reformatting requirements, the number of tools does not matter.

Where do we go from here?

The development of approaches and tools to assist in both analyzing the indicators and components and synthesizing the results to facilitate understanding of the state of the whole is in its infancy. The LUCID Project has made strides in identifying how a systems approach, and technical tools that are consistent with this approach, can help the user navigate the path of meaningful sustainability assessments. However, there is much more work including adapting improvements to existing tools, examination of alternative approaches and techniques, and developing aids to help forests use the tools.

Technical tools such as models are only aids to help us organize, synthesize, analyze, and present large quantities of complex information. In the end interdisciplinary, collaborative dialogue is the true tool for sustainability assessment.

CHAPTER HIGHLIGHTS

- Technical tools can assist in the assessment of sustainability by helping organize, analyze, and synthesize large amounts of information.
- Technical tools for synthesis and integration can help reduce complexity, highlighting areas of concerns, pursuing interrelationships, reorganizing to examine specific issues, and displaying results in easily understandable ways.
- We were interested in exploring the utility of tools that allowed us to not only summarize information and display it in useful ways but also to provide us with analytical tools that allowed us to synthesize information in a way that was consistent with our understanding (our conceptual models) of the nature of systems.
- A set of key features for technical tools were identified through the LUCID Project. These features include:
    - A knowledge based model
    - A hierarchically-based model
    - Object-oriented features
    - Spatial applications for data processing, analysis, and display
    - Capability of working with both discrete and fuzzy values
    - Ability to weight in a clear and logical way
    - Transparency
    - Documentation capabilities
    - Ability to work interactively in a real-time, scenario-modeling format
    - Capability of working with conceptual models
    - Compatibility with corporate software
- The LUCID forest teams were actively involved in evaluating and developing applications to assist in the sustainability process. Although a number of needed improvements were noted, we found that the basic modeling tool, NetWeaver, had most of the desired capabilities.
- Spatial extensions to NetWeaver were found to be very useful. There is a need for further development and enhancement of existing spatial applications to address the requirements of the tools.

Section 5: Implementation

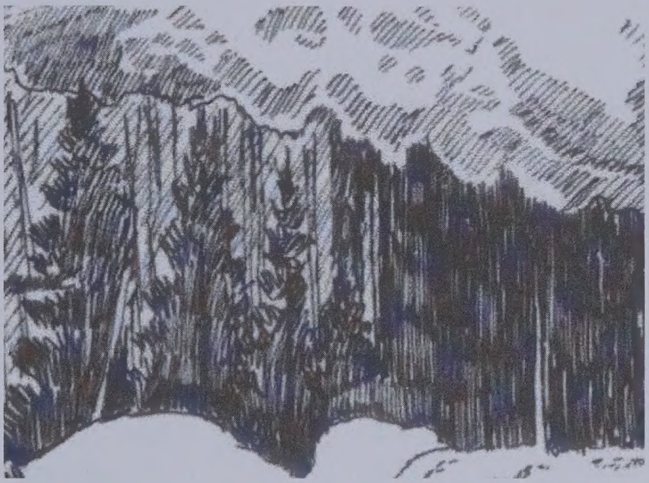
Chapter 14. Forest Management Unit Scale Sustainability Monitoring

Outlines the value and contributions of FMU-scale sustainability monitoring within an adaptive management context and highlights how FMU-scale sustainability monitoring can serve as the core component of forest plan monitoring. Discusses contributions to multiscale monitoring and raises issues regarding the relationship of C&I to independent verification techniques.

Chapter 15. Implementation: Recommendations and Conclusions

Discusses strategic and tactical implementation issues regarding the products and process of FMU-scale sustainability monitoring. Presents a series of associated recommendations including recommendations for further research.

CHAPTER 14.
FOREST MANAGEMENT UNIT SCALE SUSTAINABILITY MONITORING



FMU-SCALE SUSTAINABILITY MONITORING: THE ADAPTIVE MANAGEMENT FEEDBACK LOOP 231

- *Outlines the value and contributions of FMU-scale sustainability monitoring within an adaptive management context and highlights how FMU-scale sustainability monitoring can serve as the core component of forest plan monitoring.*

CONTRIBUTIONS TO MULTISCALE MONITORING 235

- *Discusses the relationships between FMU-scale monitoring and monitoring initiatives at regional and national scales.*

CRITERIA AND INDICATORS AND CERTIFICATION 241

- *Examines similarities and differences between C&I and certification tools.*

INDEPENDENT VERIFICATION: THE POTENTIAL FOR THIRD-PARTY AUDITING 246

- *Outlines basic issues and a set of questions for consideration when exploring the potential relationships between C&I independent verification.*

> "So how do we manage for sustainability in the 21st century? What is different? Sustainable resource management means connecting environmental, social, and economic concerns in dealing with real issues in real places with real people. ... We need to improve our capability to apply locally what we know, and we must integrate our efforts at different scales."
> (Bosworth 2001)

Forest-scale sustainability monitoring can provide both a process and a tool to help transform the concept of sustainability into "real outcomes on the ground" (Bosworth 2001). It engages people in a dialogue about what they mean by sustainability within a broad adaptive management context of assessing progress towards sustainability. Building relationships between sustainability efforts—across ideas, approaches, and temporal and spatial scales—is an important part of an overall strategy for improving management of sustainable systems.

As a result of the test projects, LUCID participants from forest supervisors to forest team members concluded that monitoring for FMU-scale sustainability is feasible and can make significant contributions to improving Forest Service management.

This chapter focuses on these contributions to improving our capability to manage for sustainability at multiple scales and in multiple ways. Section one focuses on the role of FMU-scale sustainability monitoring as an adaptive management feedback loop for forest planning and management. Section two focuses on the role and relationship of FMU-scale sustainability monitoring to management and to sustainability monitoring at other scales. The final section discusses some of the emerging issues relevant to the relationship between FMU-scale criteria and indicators, certification, and third-party auditing.

FMU-SCALE SUSTAINABILITY MONITORING: THE ADAPTIVE MANAGEMENT FEEDBACK LOOP

Adaptive management is a key component of an ecosystem management approach that can help us achieve sustainable resource management. In adaptive management managers systematically and rigorously learn from specific actions so that they can accommodate change (see Figure 46). In this context monitoring is not independent from the larger management process, and it is not an afterthought that we do with any spare resources we have.

Within an adaptive management context monitoring can be used both to help answer questions about the outcomes of management activities and to inform the next phase or round of planning and management decisionmaking. Monitoring provides feedback to forest managers about the state of ecological, social, and economic systems to facilitate dialogue and to inform the application of needed management on the ground. The sustainability assessment becomes the core, the essential feedback loop, of managing for sustainability.

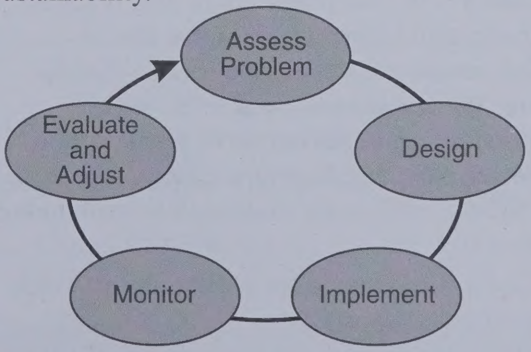


Figure 46. The role of monitoring in adaptive management.

Forest Planning, Management and Monitoring

Current forest plan monitoring is guided in part by the National Forest Management Act (NFMA) and includes minimum legally required monitoring activities supplemented by other additional monitoring items relevant to the forest. There is a great deal of inconsistency between monitoring activities on national forests and grasslands but most have a dominant focus on forest plan implementation monitoring and a tendency to focus on short-term outcomes.

Sustainability and Monitoring—the Planning Role

The sustainability and monitoring requirements of the Planning Rule (NFMA Regulation) provide part of the policy context for forest sustainability monitoring. Although broad in scope, the current drafts of the Planning Rule (2002) are consistent with the achievement of sustainability through ecological, social and economic contexts. The section of the Planning Rule Business Model dealing with the development of a forest plan monitoring strategy calls for the preparation of strategies to monitor for ecological, social, and economic sustainability.

Generally, forest plan monitoring is neither systems-based nor systematic in nature. It typically focuses on the presentation of data for individual components instead of the synthesis of components to encourage understanding of complex systems. As a result, the utility of forest plan monitoring to management is at best piecemeal.

Systems-based sustainability monitoring provides a common framework to help organize and frame monitoring activities that can be applied consistently across the national forests system. **We recommend that FMU-scale sustainability monitoring serve as the core of the forest plan monitoring activities.** Specifically, FMU-scale sustainability monitoring can be used:

1. To form the core of the monitoring activities, for forest plan monitoring;
2. To perform an analysis of existing system conditions (traditionally referred to as the Analysis of the Management Situation, or AMS) as preparation for forest plan revision;
3. As a common set of criteria and indicators to compare alternative options on equal footing and with a common language;
4. For periodic assessment of the state of systems;
5. To facilitate dialogue and engage collaborators in a discussion of a relative assessment of sustainability;
6. To provide a trigger or early warning of the need for change in the forest plan or for more detailed analysis;
7. To provide higher consistency in monitoring activities from forest-to-forest to facilitate understanding among the public; and
8. To organize and contribute to our understanding of sustainability at other spatial scales (e.g., subregional, national, and international reporting initiatives).

A sustainability assessment using the suite of C&I can provide a comprehensive way of looking at the state of systems, as well as the state of our knowledge, in preparation for forest plan revision. An assessment provides a way of analyzing the current state of the systems and facilitating understanding of the place of the national forests in the larger context and in identifying the need for change.

The collaborative approach to sustainability monitoring provides an opportunity for more participatory development of the analysis of the management situation and identification of the need for change. Although a C&I-based sustainability monitoring program will not eliminate conflicting perspectives, it will facilitate a richer dialogue in understanding those different perspectives because of the use of a common language to discuss the topics.

The benefits from this common language of C&I can extend to the comparison of alternative management outcomes. The common set of C&I can be used to compare scenarios or alternatives; and the potential outcomes and interactions between ecological, social, and economic aspects of these alternative scenarios could be discussed. Alternatives can be compared against a set of common reference values; or alternatively a comparative analysis can be completed based on differing perspectives on outcomes (e.g., emphasis on short-term versus long-term outcomes or reference values prepared from different perspectives).

From a forest plan monitoring perspective, sustainability monitoring switches the focus from short-term, implementation monitoring to monitoring outcomes. The system approach that frames the monitoring system can have broader application throughout forest planning and management as a framework for understanding complex living systems. Implementation monitoring and other monitoring requirements will still be necessary, but they can be organized within this comprehensive monitoring framework to facilitate bridging short-term actions to long-term outcomes.

A common monitoring framework that focuses on understanding the broader systems is also useful as a way to help rationalize and coordinate monitoring efforts. Often, each functional group (e.g., soils, aquatics) will propose monitoring items that are clearly related if not identical. Developing a systems-based monitoring program that frames and coordinates disciplinary measures can help identify those overlaps and reduce redundancies. In their experience in reorganizing the forest monitoring plan for the Southwest Idaho Ecogroup forests

Systems-Based Forest Sustainability Monitoring and the Southwest Idaho Ecogroup

The Southwest Idaho Group, consisting of the Boise, Sawtooth, and Payette National Forests, is a grouping of national forests with similar ecosystems components. The three forests are working together to revise their forest plans and have incorporated much of the preliminary thinking from the LUCID Project into the design of the monitoring section of the draft forest plans. The initial draft set of LUCID C&I were used as a means of organizing the forest plan monitoring section. Lacking the more developed set of C&I that included measures and the associated database, the SWI Ecogroup went through a matrix of questions emulating many of the stages of the LUCID process (see Figure 46). Indicators were examined for relevance in the context of the forest plan by identifying associated activities, practices, or effects to be measured. Each was evaluated through a set of six questions: 1) What was the question to be answered? 2) What technique should be used? 3) How reliable were the data? 4) How frequently should measures be taken and using what methods? 5) What was the reporting period? and 6) What variation would initiate further evaluation and or change in the management direction? When revised and finalized, the resulting matrix in consort with other required monitoring elements forms the core of forest plan monitoring.

P.2 Principle: Maintenance of Ecosystem Integrity							
C.2.1 Criteria: Landscape function							
Indicator	**Activity, Practice Or Effect**	**Question To Be Answered**	**Monitoring Technique**	**Data Reliability**	**Frequency and Recommend Method**	**Reporting Period**	**Variation to Initiate Evaluation and/or Change**
2.1.1 Hydrologic condition	Riparian Condition	Are management activities designed to maintain or improve riparian condition effectively meeting goals & objectives?	Proper Functioning Condition; Riparian Levels II and III evaluations (R4 Riparian Guide); or other analysis tools.	High	Three years via review of selected projects and surveys	Three to five years	Failure to achieve improving trend in vegetation composition and vigor, or other WCIs.
2.1.2 Disturbance processes	Changes in landscape character	How are disturbance processes affecting ecological and watershed conditions?	Tracking acres burned by wildfires; acres affected by major wind events; number/ size of landslide and flood events; and insect frequencies	Moderate	Annually via detection surveys, incident and fire reports	Five Years	20% change from average

(Source: Morelan 2002)

Figure 47. Subset of Southwest Idaho Ecogroup Indicator Analysis for Forest Plan

(SWI EcoGroup), forest planners found that it was relatively simple to fit each individual or functional units' monitoring need within a common framework. They also noted that when forced to coordinate groups, in most cases, could agree on measures or data that met a broad range of purposes. The ultimate result was that the overall suite of currently collected monitoring items was reduced (Morelan 2002).

Systems-based sustainability monitoring supports the analysis and synthesis of information in a way more useful for program management decision-making. The comparison of indicators to reference values over time and the synthesis of these individual comparisons into an assessment of the overall system can help identify whether management actions and priorities should be revisited.

In an active management context the process of developing reference values requires analysis of the question: What variation would initiate further evaluation and/or change in management direction? If progress is being made, management actions continue; and if not, the plan may be revisited or adjusted.

Flagging areas of concern can also lead to a more careful analysis of the appropriateness of the indicator or measure, the quality of the data, and the appropriateness of the reference value. An area flagged through monitoring might require a more detailed assessment or analysis. Using the systems framework as a guide, users may be able to hypothesize the possible effects of a problem in one area on interrelated issues in order to anticipate future problems.

Application to Daily Work and Project-Level Activities

The LUCID Project was initiated to develop a mechanism by which systems sustainability could be assessed. The primary intent was to develop a tool that would provide feedback specifically at the FMU scale although data could be obtained from a range of finer scales (Chapter 3). In their evaluations, however, **LUCID participants noted that the tool and techniques have application on a daily basis at a range of scales including at the project level.**

Providing a Context and Frame of Reference

The systems framework provides an integrated approach to monitoring a way to understand the complexities of ecological, social, and economic systems. It also is a framework that can be used at multiple scales. Whether with Forest Service employees or collaborators, a deeper understanding of these complex systems can help put each management decision and action in context and can facilitate integrating different components. Although project-level monitoring is more likely to focus on tracking more specific measures in detail (e.g., the impacts of a harvesting system on forest structure), the broader systems framework and more comprehensive FMU-scale monitoring approach can provide a context in which to analyze and understand project-level effects.

As a Way to Discuss Values

A common critique of national forests management is that it does not accommodate (or at least does not obviously acknowledge) people's values. In the quagmire of procedures and paperwork for each project and action, it is rare where there is an explicit opportunity to discuss values. Environmental Assessments (EA's) are criticized because "there aren't any values in them." Indeed, in the professionalization of resource management it is typically perceived as highly desirable that decisions and procedures are "value-free." Timber yield tables, for example, indicate specific values based on high quality, large diameter, densely stocked stands that can be maintained and regenerated over time at low costs in order to optimize productivity. Of course, no decision is value free; and a timber-yield table could be equally developed from the perspective of other sets of values. However, within resource management we have found it difficult to find a way to uncover and discuss values productively.

The LUCID team leader and forest planner from Ottawa National Forest, Bob Brenner, highlighted the contributions of a new way of thinking facilitated by sustainability monitoring to address the issue of values. Each time something is put into the design of an environmental assessment or project activity (e.g., the establishment of harvest units, the choice of silvicultural practices, the prioritization of habitat for a riparian species, or establishment of a new trail) we can be more explicit about values, about whether things come together and where they don't. Bob suggested that each project or decision could be broken into pieces, and for each piece the question of "why" answered in order to reveal values. Alternatives could be proposed and the relationships of items discussed.

In this context, indicators and reference values, and the broader language of sustainability that develops from using them, could be used to help understand the implications to the system of the choices and decisions and the nature of the choices, the values that were involved. A subset of related indicators or measures could then be tracked to monitor the outcome. Bob pointed out that this approach is not really about extra work; but rather, it means being explicit about what is already being done. By opening up the discussion of values and by providing a way and a place for people to discuss them, we may be able to help provide a *forum for discourse* with the public about their values and our stewardship of national forests.

CONTRIBUTIONS TO MULTISCALE MONITORING

Building relationships between sustainability efforts across ideas, approaches, and temporal and spatial scales is an important part of an overall strategy for improving management of sustainable systems at multiple scales. This section begins with a more general discussion on the value and meaning of multiscale relationships. It then explores the relationship between forest scale sustainability monitoring, using the LUCID Project as the example, and other sustainability programs or approaches. A detailed examination between any one of these other programs and the LUCID Project could be very intensive. The intent of this section is to provide an overview of the potential relationships and to surface issues, questions, opportunities, concerns, and areas that should be pursued in more detail in the future.

The Value and Meaning of Multipurpose and Multiscaled Relationships

There is no right scale to assess or manage for sustainability; a comprehensive approach would involve managing and monitoring sustainability at multiple scales. Although sustainability can be studied at multiple scales, once the components of systems are identified for monitoring selecting the correct scale is critical. The context of the systems that we are trying to sustain changes at every scale because the constraints change. So even though managing for sustainability requires thinking across all scales, monitoring and assessing sustainability must be based on the recognition that there are different questions and different methods used at different scales. Using the wrong scale to look at certain system properties would be like trying to see an elephant through a microscope. Consequently, the sustainability questions, the measures and reference values, must change.

Clearly, integrating sustainability initiatives across scales is an admirable goal. Integration would support our desire to increase our understanding of sustainability at larger scales and improve our ability to manage at local scales. Reducing process gridlock and increasing efficiency are also desirable objectives of integration. For the public clarifying the relationships between initiatives can facilitate transparency and understanding and support the intent of coordinated government actions. The means by which sustainability initiatives are related, however, depends a lot on what we mean by integration.

Throughout the LUCID Project we have encountered and discussed a range of different perspectives on integrating or linking sustainability monitoring initiatives. These perspectives are often phrased as a question about how things are related or, how and why they are different, including:

1. Are the goals of the initiatives the same? If so, why do we need more than one program?
2. Are the frameworks the same? If not, why are different frameworks used? Can FMU-scale indicators be organized under other frameworks?

3. Are we monitoring the same elements (criteria, indicators, measures)?
4. Can we collect common data?
5. If we monitor at smaller spatial scales, can we: a) Aggregate the results to understand the larger picture? b) Understand the influence or effect of the state or condition of one area (e.g., a national forests) on another (e.g., a region)?
6. What can we learn from sustainability monitoring at one scale to benefit our understanding of sustainability at other scales?

Unfortunately, for each of these questions there is no easy answer; and those looking for an answer as simple as a crosswalk chart will be dissatisfied. Our attempts to answer the questions and to propose ways that sustainability monitoring can be integrated at multiple scales leads us into discussions of: the nature of human values and the role of communities of place and communities of interest in forming our values; the nature of living systems and the inherent variability in their form and expression; and the methodological challenges associated with data integrity, sampling, and aggregation.

Since many of these topics have been discussed earlier in this report or are best explored in detail in other forums, this section simply presents a summary of the issues associated with identifying these relationships. Following these sections, we focus on regional scale assessments and the national framework for sustainability monitoring, the Montreal Process C&I.

The Context of Systems

Ecological, economic, and social systems are living systems consisting of components that interact in hierarchical and nonhierarchical ways such that they are more than the sum of their parts. While we can describe the ecological systems of the eastern hardwood forests of Allegheny National Forest and the ecological systems of the dry range, pine-juniper woodlands of the Blue Mountain Forests using a common framework describing the structures and functions of each type of ecological system, the system elements vary in type and temporal and spatial scale. The landscape patterns and structure of the dry western Blue Mountains is driven by large-scale ecological disturbance functions such as fire. In the East the landscape patterns and forest structures are affected by small scale, patchier disturbances from individual tree replacement caused by disease, root rot, localized weather events, and the effects of deer browse on selection and regeneration. Thus, to understand the state or outcome of systems, the measures, data elements, and reference values must be adapted to local contexts.

The emergent properties of systems are unique to the system under study. As humans, we are clearly more than the sum of our parts. Our structures, like our DNA, and functions, like our circulatory and nervous systems, interact in ways that result in a human being that is clearly more than the sum of its parts. The emergent properties that result from the pieces of DNA and the functions of the nervous system result in sentient thought—something that can't achieved by simply placing all the pieces of humans in a bowl and stirring. And barring belief in a collective conscience on the magnitude of the Borg from Star Trek fame, the ability to think and reason is a property of individual (organism) human systems and not of human population systems. Ecological, social, and economic systems likewise have emergent properties that are unique to each. Although some structures and functions are common between kinds of system, the "whole" is specific to the kind of system under study. Thus monitoring the state of systems at one scale cannot be used to understand the state of systems at another scale because the emergent properties, the whole, changes as the systems change.

The Nature of Values

The concept of sustainability captures a set of complex human values about our desired state. Like justice and truth, sustainability is hard to pin down because our values are unique and variable. The formation of human values is influenced by what we experience (and at what scale), how we experience it, and with whom. Our desired future conditions for a national forests, an expression of our values about sustainability, are formed by the specific place and our experience with that place and by the group of people, the community, we are a part of. What residents of Portland, Oregon, value for the future of Mount Hood National Forest may vary from what they value from other national forests outside their experience or that they have experienced in a different context. Similarly, ranchers' expressed values for desired future conditions of the Blue Mountain Forests may be different (although not necessarily) from those involved in harvesting nontimber forest products.

Consequently, assessing sustainability requires that we customize the desired future system conditions (reference values) to the specific location. In similar ways the measures (and potentially even indicators) will vary since what we value will vary with the location, the scale, and the needs and desires of those who are involved or affected. Income and employment may be topics or attributes of value in our discussions of sustainable forest management at large spatial scales (the scale of a Nation or State) and at smaller spatial scales (the scale of an individual forest management unit). At a national scale questions for monitoring related to income and employment may focus on trends in employment numbers in forest-related sectors, employment shifts between forest sectors (e.g., forest product harvesting to recreation and tourism), and associated income values by sector. At the FMU scale questions about employment and income may result in measuring different things in different ways because of the scale at which the question is asked and what humans value. Statewide or national employment in the forest-product sector could be steady, but the mill in the community next to a given forest may have just closed. The measurement method and the reference value will need to change to focus on the employment and income values at that scale and may include a focus on distributional equity issues for employment and income levels, of the rate of change and the capacity of the community to absorb that change, and in the nature of employment opportunities (Are they good jobs? Are they safe?). Thus, even though many attributes (e.g., employment) are common across monitoring initiatives, their meaning and value are scale-dependent and reflect the values of the communities of interest and communities of place.

Methodological Data Challenges

Chapter 3 of the report discusses issues related to the scale, data collection and aggregation. Methodological challenges such as collecting data at one scale and using it at another scale have to do with the kind of data, the sampling and measurement methods, estimates of error, and issues of data intensification. Under the right conditions some data can be used at multiple scales, but resolving the applicability of data sharing between scales involves resolving questions associated with methodological challenges.

Regional-Scale Assessments

Regional assessments typically examine the conditions of ecological areas. The Interior Columbia Basin Ecosystem Management Plan (ICBEMP), the Northwest Forest Plan, the Sierra Province Assessment and Monitoring framework (SPAM), and the Great Lakes Assessment (GLA) are examples of regional assessments. In their current configuration, regional assessments have a range of different purposes with some focusing more directly on sustainability and others focusing only on a subset of sustainability issues (e.g., ecological aspects). These regional-scale assessments may be larger planning and management processes (e.g., Northwest Forest Plan) or they may focus more specifically on the monitoring and assessment phase (e.g., GLA). The monitoring components of these various regional assessments vary considerably from those with monitoring frameworks more consistent with systems-based approaches (e.g., SPAM) to those with monitoring frameworks constructed to emulate the administrative sustainability monitoring programs of the Montreal Process (e.g., GLA).

Given the differences in purpose, focus, and organization of existing regional assessments the relationship between FMU-scale sustainability monitoring and

Internal vs. External Perspectives

Chapter 2 discusses the differences in understanding that is gained from monitoring from internal versus external perspectives. Examining the structures and processes of regions from an internal perspective (the cumulative effects of FMU-scale assessments) provides an understanding of the detailed components within systems and can provide understanding of how the two scales interact. An external assessment looks at the consequences of the internal components and processes. Both perspectives are valuable, but they are different.

these assessments varies. Within the LUCID Project a few of the forest teams were able to use information generated from regional assessments as sources of monitoring information, as sources of regionally appropriate reference values, and as context for the FMU-scale initiative.

In the future, regional-scale sustainability assessments could fill a unique niche in understanding and managing for sustainability. Regional sustainability assessments provide a unique lens to look at the cumulative effects of management for sustainability at the FMU scale and to understand the larger context of FMU systems. To fill this objective, regional sustainability assessments could implement a coarse application of the FMU-scale sustainability monitoring criteria and indicators. Regional assessments may also include other kinds of systems (e.g., regional economies, biomes) best assessed across broader spatial scales than at the FMU scale. Optionally, regional assessments could be supported by data collected uniquely to support this specific scale of assessment and focusing on the scale-dependent questions of the region.

National Framework for Sustainable Forests: The Montreal Process C&I

As briefly outlined in Chapter 1, the Montreal Process C&I provides a common framework for describing, assessing, and evaluating progress towards sustainability at the national level (Chapter 1). The United States along with 11 other countries agreed to report on progress towards sustainability using this common framework. The Montreal Process C&I provides a framework of seven criteria and 67 indicators that serve as a national framework for sustainable forest management (Appendix 15). The C&I describes forest conditions, attributes, or functions; the functions associated with environmental and socioeconomic goods and services that forests provide; and the overall policy framework, institutions, and processes that enable society's efforts to achieve sustainable forest management. In 2003 the United States will report on its progress toward sustainable forest management with a national report developed cooperatively among Federal agencies and through the participation of a broader multistakeholder forum of government and nongovernment interests, the Roundtable on Sustainable Forests.

> *"On November 5, 1993, following the United Nations Conference on Environment and Development (known as the Earth Summit) in 1992, Presidential Decision Directive NSC-16 was signed which states '...The United States is committed to a national goal of achieving sustainable management of United States forests by the year 2000.' On February 3, 1995, as an endorser of the Santiago Declaration, the United States agreed to use the C&I as the framework for discussing national progress toward sustainable forest management. Using the C&I, the United States government will report by 2003 on the state of the Nation's forests, including both private and public lands, and progress towards sustainable forest management in the United States"*
> *(United States Government 2001)*

Although the Montreal Process C&I was principally designed for use at the national scale they are also being applied at subnational levels such as states. The following sections discuss the relationship between FMU-scale sustainability monitoring and the national sustainability framework organized by the questions presented at the outset of this section.

Complementary but Different Goals

The various sustainability initiatives have complementary goals to help achieve sustainability, but they also have different purposes and focuses and consequently a need for different tools. National reporting frameworks, such as the Montreal Process C&I, focus on reporting on the state of the nation's forests in broad terms and on the policy and institutional frameworks for sustainability. The focus area for these national frameworks is on the status of forest sustainability within administrative (e.g., State or Federal) boundaries. Whether the focus is on the extent to which protected areas are used as a mechanism for conservation or in investments in forest growth, the goal is to ensure a strong policy and institutional context to achieve sustainability. Initiatives serving to meet this goal can be accordingly framed by the key issues or objectives that the administration wishes to emphasize.

Sustainability assessment tools such as FMU-scale monitoring have as their primary goal an assessment of the state of ecological, social, and economic systems. The purpose is to provide feedback on the short-term and longterm outcomes of the state of systems to guide planning and management activities. Sustainability assessments then need to be framed based on the properties of systems at the scales of study.

Clearly, both initiatives are complementary. A strong national framework provides the policy context and structures to enable on-the-ground management for sustainability. The results of national sustainability reporting, for example, may identify broad trends and trigger interest and attention on specific issues. Likewise, improvements in the state of the nation's progress towards sustainability are facilitated by actual changes on the ground. There is clear philosophical overlap and interdependence between the two initiatives although the tools and approaches are different and therefore not easily translated one to the other.

> *"[N]ational-level sets of criteria and indicators for various regions of the world should be complemented by the development and implementation of sets of criteria and indicators defined at the forest management level."*
> *(Castaneda 2000)*

The Need for Different Frameworks

Chapter 2 of this report discusses the different possibilities in framing the development of monitoring systems. This section elaborates on those differences through a set of focus questions.

1. Why do the frameworks differ?

As the previous section on goals discusses, the different purpose or specific goals for these sustainability initiatives is one of the drivers that results in different organizing frameworks. The FMU-scale framework is based on understanding systems and the national framework is based on a combination of broad international goals and issues. At the FMU scale this systems approach was seen as particularly relevant since it provided a mechanism to organize our understanding of the contexts that we are trying to sustain: the ecological, social, and economic systems. At the national level the framework development was focused less on understanding system properties and contexts than on policy contexts and issues of broad concern not just at the scale of a nation, but of concern across multiple nations.

2. Why can't the FMU scale use the national framework based on the seven criteria or, could the systems-based C&I now be reorganized under the Montreal Process C&I?

Part of the confusion between the differences in frameworks is that many of the monitoring elements, at the broad level, look the same and use similar terminology. Both C&I initiatives, for example, focus on income, on riparian conditions, and on recreation. Indeed, some of the measures are likely to be identical although sampling intensity will clearly vary; and reference values (if they were to be developed at a national level) would need to be different.

But beyond the individual elements the primary difference associated with the frameworks is the fact they are saying something different. The national framework provides an organizational structure to report on the condition of a range of individual elements grouped in common themes. The intent is to report on indicator status and over time to examine the trends for that indicator. FMU-scale sustainability monitoring is attempting to report on the state of systems and specifically the structures and functions of those systems. Although indicator status and trends will be investigated, the assessment component of the FMU-scale initiative is accomplished by comparing indicators to reference values and synthesizing the results to understand the state of the systems and its emergent properties.

Physically, it would be very easy to take the indicators and measures developed for FMU-scale sustainability monitoring and categorize them under the Montreal Process criterion. The result of such a crosswalk would show great similarity except in the area of legal and institutional structures. However, to reorganize systems-based indicators from their systems context strips them of meaning.

Monitoring Elements and Data Sharing

3. Are we monitoring the same elements (criteria, indicators, measures)?
4. Can we collect common data?

The preceding discussion notes that many of the indicators included in national and FMU-scale C&I initiatives are conceptually similar. In some cases not only are the indicators the same, the questions that would be addressed are similar enough between scales that the same measure could be used to verify the indicator. Often, however, although the same piece of raw data may be used at multiple scales, the sampling locations, intensity and kind of analysis will vary because the sustainability question will change between scales.

Where shared data elements can be identified between scales, monitoring efficiencies can be achieved. FMU-scale monitoring will typically require complete characterization of indicators and more intense sampling in order to understand the variation at that scale, but it may be that only the measurement protocol is shared and not the actual data collection process. As measurement protocols and data elements are more clearly specified for Montreal Process monitoring at the national level, it will be easier to identify potential opportunities for data sharing.

Aggregating Results

5. If we monitor at smaller spatial scales, can we:
   a) Aggregate the results to understand the larger picture?
   b) Understand the influence or effect of the state or condition of one area (e.g., a national forests) on another (e.g., a region)?

Looking at the results of the FMU sustainability assessment as a whole aggregating the results of one FMU assessment to another scale is not feasible. The emergent properties of a system make it unique and cannot be aggregated to another scale.

Within the FMU-scale sustainability-monitoring program, we explored the feasibility of using a spatially based analytical tool to help in working with multiscaled data. GeoNetWeaver was selected for the project because data for different measures were associated with different spatial layers or units. Some data, for example, were best measured and understood by watershed while other data were best measured and understood by county. The data were associated with those spatial layers or units because that was where the indicator or measure for that system component had the most meaning.

Some people have also expressed interest in applying this spatially based tool to aggregate or understand sustainability at other scales. This would be potentially valuable, for example, to understand the relative contribution to sustainability (of one area with a larger area). However, without data collection across all coverages (for both the smaller and the larger study area) we would need to develop a tool that could help appropriately project or forecast the values to another area; and this is beyond our current level of expertise. Where data have been obtained for the full range of areas of interest, it is quite possible to examine the relative contribution of one area (using area-weighted averages based on the area that achieves the reference value) within the larger analysis area. Within the context of FMU to national level sustainability monitoring this is unlikely.

In understanding the relationship between initiatives at different scales, we found that the most value comes from narrative descriptions that describe the results in a context fashion. Narratives can be used to describe this "rich" picture.

Other Relationships Between Scales

6. What can we learn from sustainability monitoring at one scale to benefit our understanding of sustainability at other scales?

Given the desire to achieve a cohesive and integrated approach to sustainability but also given the relatively limited scope to directly share information that is scale dependent, what can we learn from sustainability monitoring at one scale to benefit our understanding of sustainability at other scales? In short, what can FMU-scale sustainability monitoring offer to the national framework and vice versa?

National, regional, and FMU-scale criteria and indicator programs represent complementary tools in our quest for sustainability. Each tool or initiative helps answer a set of questions and provides feedback for different kinds of purposes and decisions at different scales (Figure 48).

One valuable lesson from the LUCID Project that can contribute to other monitoring initiatives is associated with the process of sustainability monitoring and in the growing dialogue about sustainability. From a process perspective the LUCID forest teams learned a series of valuable

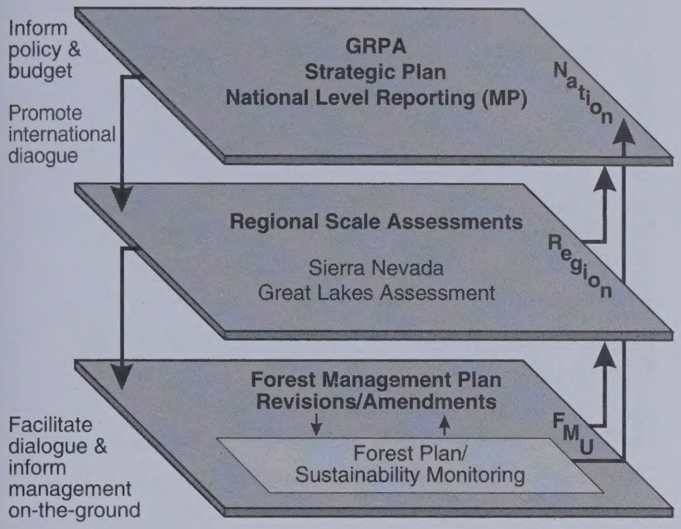

Inform policy & budget
Promote international diaogue
GRPA
Strategic Plan
National Level Reporting (MP)
Nation
Regional Scale Assessments
Sierra Nevada
Great Lakes Assessment
Region
Forest Management Plan Revisions/Amendments
Forest Plan/ Sustainability Monitoring
FMU
Facilitate dialogue & inform management on-the-ground

Figure 48. Relationships Between Multiscale Monitoring for Different Purposes

lessons that we feel have application to other processes. Highlights from a few of these are summarized below.

1. **Value in the details**—The LUCID participants were required to specify indicators, measures, data elements, and reference values for each component and to document why they selected it, how it was related, and the accuracy and sensitivity issues. LUCID forest teams emphasized that the more specific they had to become in describing the monitoring program the more they understood what was important to monitor. Currently technical teams and individuals working through the development of measures for Montreal Process reporting for the 2003 report are engaged in examining measurement issues. These technical teams may benefit from the lessons learned and some of the general approaches and tools of the LUCID Project.
2. **Understanding interrelationships**—For LUCID forest teams it quickly became apparent that sustainability, and consequently sustainability monitoring, was about more than individual indicators or pieces of data. Understanding sustainability required understanding how things were connected and related even if we were as yet unable to fully understand all of those relationships or find ways to probe those interactions. Finding tools and processes to begin to understand these interactions is critical.
3. **Interdisciplinary approaches**—While technical tools like computer models were useful to some assist with analysis and synthesis, the primary mechanism to understand the interactions and connections was the human mind. Working within a systems framework in interdisciplinary groups ultimately led to a rich understanding of sustainability. Although it was tempting to bend to the pressures of time and take a set of indicators or measures and independently develop protocols for them or reference values, LUCID participants noted that tests benefited most from the times they worked together from building broad conceptual framework models of sustainability and the frameworks they were using to discussing and challenging choices of measures and reference values.
4. **The need for collaboration**—Based on the importance of including a full range of values in an assessment of sustainability, LUCID participants strongly recommended fully collaborative approaches to address the critical issues of everything from where and with whom sustainability assessment should occur (the scale issue) to finding data and interpreting results. The Montreal Process' use of a multistakeholder roundtable is a very positive opportunity to facilitate this kind of input.

CRITERIA AND INDICATORS AND CERTIFICATION

As discussed in Chapter 1 criteria and indicators and forest certification are two different, but potentially complementary tools that have been developed to address the issues of sustainability. The current policy (as of Fall, 2001) for national forests system lands directs the Regional Foresters to "… refrain from making any commitments to, or pursuing any agreements with, third party certifying organizations on national forests lands." Forest laws direct the expectation that public forests will be managed in a responsible and environmentally sound manner including management of both commodity and noncommodity outputs.

Although the LUCID Project was explicitly a C&I initiative and not a certification initiative, we were constantly asked how C&I relates to certification including:

- How are C&I and certification different?
- Do we need to do both C&I and certification?
- Are there benefits from using both tools?
- Should government be involved in certification?
- Will C&I evolve to become a certification system (or vice versa)?
- Are both tools accessible to all or are some users more likely to select one?

Questions about the similarities and differences and the nature of the relationship between these two tools will be increasingly raised the more that the national forests system becomes engaged with partners and collaborators. For example, several individual landowners and some of the states containing LUCID forests (e.g., Pennsylvania) have embarked fully into the certification arena. As a result, there is a specific need to compare and contrast the two tools so that the questions regularly posed to participants in the LUCID Project are clarified[1]. Both C&I and certification are important tools in the overall sustainability toolbox, so there is a need and opportunity to share ideas and explore how they might work in a complementary fashion. In this section we briefly address some of the key features of each tool and discuss the similarities, differences, and opportunities.

Criteria and Indicators

C&I was initially developed "In response to countries' demands for practical ways of assessing and monitoring sustainable forest management at the national level and as benchmarks to measure and report progress towards sustainability" (FAO 2001a) although it has evolved into a tool that is used at multiple scales. Currently, more than 150 countries are involved in approximately 9 major C&I programs related to sustainable forests with many other organizations and governments participating in individual initiatives. Although these initiatives vary in scope, scale, and process, they typically share common elements (e.g., forest principles).

National-scale C&I was developed in response to the Forest Principles of Agenda 21 (see Appendix 2) with a focus primarily on contributing "to the development and regular updating of policy instruments (laws, policies, regulations)" (FAO 2001a). The intent of national suites of C&I like the Montreal Process is to "provide a framework for measuring the ecological, social, and economic conditions related to the forest" in order to "enhance national dialogue about sustainable forest management" (Washburn and Block 2001). The C&I helps provide a "common language with which to examine our understanding and measure the current state of the three elements of sustainable forest management" (Washburn and Block 2001). The Montreal Process framework consists of seven criteria organized by a broad sustainability goal and 67 indicators that are characterized by a mix of performance outcomes indicators, enabling conditions, and policy or management process indicators. Measurement protocols and reference values are not part of the Montreal Process suite of indicators although each nation implementing the MP C&I have been focusing on the development of measures and data availability. To date, the focus in the application of the MP framework has been on assessing and reporting trends over time in the indicators at the nation or state (subregional) level.

Forest management unit scale C&I initiatives have as their first focus improving forest management on the ground "so as to contribute to meeting established national goals" on sustainable forests (FAO 2001b). Within the North American context FMU-scale applications of C&I (e.g., CIFOR-NA, LUCID Project, Canadian Model Forest LLI program, Mexican FMU initiatives) have developed scale-specific C&I for sustainability focused on multi-owner jurisdictions as has CIFOR's internationally based FMU-scale program. These FMU-based applications have included a mix of types of indicators with the LUCID Project focusing on outcome measures of systems structures and functions.

---

[1] We have not attempted to address the policy questions about the role of the government in certification in this section because this is outside the scope of the project.

> *"Taken together, criteria and indicators provide a mutual understanding and implicit definition of what is meant by sustainable forest management. They are tools for assessing trends in forest conditions, and they provide a framework for describing, monitoring and evaluating progress toward sustainability. It is important to note, however, that the criteria and indicators are not to be used as performance standards for certifying management or products at any level."*
> *(National Association of State Foresters 1999)*

Certification

Certification is a market-based tool that at the broadest level is "designed to document and reward sustainable forest management practices, and assure consumers of forest products that their purchase comes from a well-managed forest" (Washburn and Block 2001). The goals of certification are diverse:

- To recognize good forest management;
- To improve forest management systems;
- To improve producers' relations with stakeholders;
- To improve producers' status and claims to resources;
- To reduce regulatory enforcement burden;
- To ensure market access; and
- To ensure a social license for forestry and to build political clout.

Worldwide, there are a large number of certifying systems and certifiers; but most are voluntary in nature with a focus on the forest management unit or ownership level. The intent is to "evaluate forest management practices against a set of standards" (Washburn and Block 2001) in order to gauge compliance. Increasingly, certification also includes a third-party auditing component. Independent verification or third-party auditing will be discussed in further detail in the following section.

The certification movement is expanding worldwide. Today, more than 60 million acres are certified worldwide (up from less than 2.5 million acres globally in 1995) by the Forest Stewardship Council (FSC) with more than 7.7 million in the United States alone. The certification program of the American Forest and Paper Association, the Sustainable Forestry Initiative (SFI), has enrolled

Certification System Profiles

There are numerous certification systems and certifiers involved in sustainable forestry globally; and the focus of these certification systems varies from certification of forests, to certification of land managers, to certification of forest products within a chain-of-custody scenario. Three of the most frequently cited certification systems in the United States are profiled briefly here.

Forest Stewardship Council (FSC): FSC is an independent, international nonprofit organization involved in forest certification globally. The certification system and standards were developed jointly by representatives from environmental, social and forest management groups and based on 10 general principles of sustainable forestry and 56 specific indicators. FSC is working towards the development and adaptation of regional standards in a similar collaborative forum. Independent, third-party auditors accredited by FSC examine forest management at the field level with most indicators emphasizing on-the-ground reporting. Public reporting of the overall audit results is mandatory.

Sustainable Forestry Initiative (SFI): SFI is the program of the American Forest and Paper Association (AF&PA) and participation in SFI is required of all members. The SFI system consists of five principles with a series of implementation guidelines that include 11 objectives and 35 performance measures. A range of verification options from first-party to third-party verification are presented; and those who select the third-party certification program are audited against a mandatory set of "core indicators" at a minimum. The SFI system focuses on process-based measures including policies, plans, and management. Public reporting is not required although many companies who participate in third-party certification do publish the final results.

ISO 14001: The International Organization for Standardization (ISO) is an international body involved in the development of technical standards in a range of areas. The ISO 14000 series focuses on environmental management systems (EMS). Although the EMS system is general in nature without specific performance requirements, it focuses on improving environmental performance through planning and management activities and certification of the forest operation's management, not the on-the-ground activities themselves. Self-declaration of compliance with the 14001 EMS standard can occur with third-party auditing an option.

more than 100 million acres with approximately 85 million acres of that committed to third-party certification by June of 2002. Other, more regionally focused certifiers have certified very large areas of land. It is not uncommon now for companies to acquire multiple or stacked certifications (for example, ISO 14000 series and FSC certification). To date, most certification is the purview of larger companies, typically those involved in exporting (80 percent are in temperate/boreal forests and 88 percent in industrial/State forests) with smaller groups or companies often subsidized.

Similarities

In addition to the overall goal of sustainability, C&I and certification have a number of other attributes in common. Both are nonregulatory in nature and typically voluntary in scope. From a content perspective many of the individual elements included in the C&I or certification performance standards are based on the same core set of ideas and can be related back to the Agenda 21 Forest Principles.

In some places there is an even tighter link between the tools. For example, the International Tropical Timber Organization (ITTO) uses C&I as a basis for certification activities.

Differences

While C&I initiatives originated as a national scale tool, they are increasingly being applied at multiple scales. Certification is predominantly a small-scale tool typically focused on individual ownerships or collectively managed forest management unit areas (e.g., all State forests within Pennsylvania).

The C&I audience varies from policy-making to managers and collaborators, particularly with publicly owned forests. The primary audience for certification is within the marketplace although increasingly ownerships or companies are reporting to broader audiences.

One of the primary differences between C&I and certification systems is based on the types of indicators or measures. The type of measure affects a number of other issues including the focus, scope, orientation, and temporal scale issues. Management process/performance measures, enabling condition measures, or legislative and policy measures describe a class of measures designed to determine whether a management (at whatever scale) process is in place or being complied with. Number of acres meeting best management practices for soil, miles of streams meeting EPA water quality standards, or compliance with Occupational Safety and Health Administration (OSHA) worker safety laws are examples of these types of measures. These types of measures tend to be the focus of many certification systems (exclusively so within ISO systems and predominantly within SFI) and the majority of the socioeconomic indicators and many ecological indicators within the national C&I framework.

Outcome-based measures focus on describing the state of the system—the condition of the system attribute (either structure or function) that exists. The number of worker safety incidents (e.g., lost-time injury frequency rate), an assessment of landscape patch distribution and connectivity or the population sizes of selected species at risk are examples of outcome-based measures. Many national level C&I ecological indicators, some FSC indicators, and the majority of LUCID C&I are outcome-based measures.

Some people have described the difference between C&I and certification as the difference between a descriptive and a prescriptive approach. This comparison is too general, however, because it depends not only on the type of measure (see below) but also on whether or not reference values or standards are included. To date, national scale C&I applications have typically not contained reference values and the chief objective has been to describe the condition of the indicator. Consequently, national-scale C&I could appropriately be described as "descriptive"' in nature. FMU-scale applications of C&I are increasingly included reference values, however, as with LUCID, most specifically indicate that the reference value is locally developed and adapted. Since the focus of LUCID indicators and measures has been on assessing the structure and function of systems that are unique to each given environment, there is no attempt, nor is it feasible, to compare different forests against the same set of standards. These approaches move beyond "descriptive" as a characteristic; but because reference values are developed and adapted locally, they are not truly "prescriptive." Certification systems by their nature need to adopt a common set of standards (even if they are regionally defined as within FSC) in order to ensure that each forest/manager is compared against the same set of reference values. When the means of verification of the elements (e.g., indicators) focuses on management performance (e.g., the percent of streams exceeding EPA water quality standards), these comparisons are much more easily facilitated. In this sense, certification systems are more prescriptive.

The scope or content of the material contained within C&I suites and certification systems typically cover the same range of concepts. Initially, many certification systems had relatively limited focus on the social and economic dimensions; but increasingly, the content coverage is equally broad.

Criteria and indicators are a monitoring tool that is repeated over time. Many certification systems (for example, FSC) also have a renewal or re-certification phase. There are broader temporal scale differences between the two tools, however. The time frames of applicability of C&I and certification vary depending on the kinds of measures (and their associated standards/reference values) that are included. Individual measures

Overlap Between C&I and Certification

In 1998, CIFOR worked with two certifiers, SmartWood and SGS, to conduct a certifier evaluation and field test of the CIFOR generic C&I. The intent was to assess and field test the suitability of the generic C&I in terms of practicality, objectivity, cost-effectiveness among other things, and to evaluate whether the generic C&I adequately assesses the quality of management performance in a way that would be compatible with certifying systems. A paper comparison was followed by a field-based exploration of the idea of C&I and an independent, external audit of an FMU's performance on the ground in Indonesia.

Performance auditing "is a specific form of monitoring which compares designed (i.e., expected or intended) versus actual performance" (Blakeney et al. 1998). The audit itself may take the form of a set of written expectations (quantitative or qualitative), an auditing standard or checklist, or a management plan. The comparison is between the stated requirements and the actual performance. As the authors note, the audit teams typically collect little primary data but rather concentrate on verifying whether the procedures or performance measures have been followed. Evidence that the audit team might look for may include:

- That the FMU has designed a scientifically acceptable program for monitoring;
- That the monitoring has been implemented as designed;
- That data are analyzed in a careful and scientifically accepted way; and
- Results are used for forest management and decision-making (adapted from Blakeney et al. 1998).

Performance-based audits are facilitated by the adaptation of verifiers to the local level, with reference values or standards for each, and sufficient documentation. Verifiers that focus more on policy level issues are less useful in this regard. Following an initial assessment and review of the lists of C&I, performance-based audits may include site visits, a review of documents, and meetings with range of personnel including collaborators.

The auditors made a number of findings including:

- Policy indicators, the institutional framework conducive to sustainable forest management, are important but because they are beyond the control of forest managers they are inappropriate for local assessment.
- Auditing was much easier for indicators that focused on management and its impacts rather than on outcomes. The auditors proposed that indicators could be adapted for auditing by taking critical outcome-based measures and relating these to operational practices focusing on implementation.
- All measures need standards.
- Clear and consistent language is needed for all elements both in their wording and in the consistent use of the hierarchical levels of principles, criteria, and indicators.
- Indicators and measures should be generic enough to apply to a range of places (e.g., "community guild structures do not show significant changes") and not so specific as to be only narrowly applicable (e.g., "abundance of nests of social bees"). The auditors recommended that measures might be prepared as a list or menu of potential options that could be selected depending on their applicability.

Source: Adopted from Blakeney et al. 1998 with C&I and certification systems that are management performance based (e.g., policy, enabling condition) tend to have a relatively short time frame. Outcome-based measures within C&I and certification systems have a mix of short-term and long-term time frames. Many certification systems (e.g., SFI) tend to be focused much more exclusively on management performance measures and so tend to have a short-term focus whereas the LUCID suite of C&I includes more outcome-based (state of system) measures with longer time frames. National level C&I represents a real mix of types of measures with social and economic measures predominantly management performance/enabling condition focused.

Different but Complementary

Overall, the two tools, C&I and certification, may best be viewed as complementary and not exclusive options. At the national scale, where the focus is more on policy and enabling conditions in establishing a forest management framework, a suite of C&I that includes a mix of outcome and policy-based indicators may provide the needed information. At the local, or forest management unit level, the choice of the appropriate tool will largely depend on the objectives of the land manager.

Where the objective is focused on providing a means of certifying the approach to management in a systematic and standardized way to enable comparison against some agreed upon set of norms, certification is typically the approach. Certification assumes that all those certified meet the same set of standards and the need for common standards has led to a focus on measuring management performance or behaviors within an *implementation* monitoring type framework. Criteria and indicators, applied at the local level, have a focus on the outcomes or state of the systems.

The two tools can clearly be used in a complementary fashion where the C&I tool can provide the mechanism to gather the information and perform analysis necessary for certification. Similarly, where the certification stamp provides a point in time (even if it is repeated) assessment of compliance with a set of management standards, criteria and indicators that focus on outcome-based measures will provide the feedback to management on whether the management actions are leading them in the desired direction. The choice of which tool to use will depend largely on the management focus or objectives and the match with what the tool can provide. Some jurisdictions, including several community forests (Ejidos) in Mexico, are engaged in or considering using both tools in their overall approach to sustainability.

INDEPENDENT VERIFICATION: THE POTENTIAL FOR THIRD-PARTY AUDITING

Independent verification (commonly referred to as third-party auditing) is one of the key attributes of many certification systems although its use is not limited to certification. The intent of an independent verification system is to provide a neutral assessment of the validity of a claim with a perceived benefit of improved credibility. ISO 14001 for example defines auditing as a "systematic, documented verification process of objectively obtaining and evaluating audit evidence to determine whether specified activities, events, conditions, management systems, or information about these matters conform with audit criteria."

Verification—evidence of the truth of something; to prove the truth; to confirm; to substantiate.

Auditing criteria have typically been related to evaluating forest management performance in terms of inputs or outputs or the characteristics of the management system in place and as such as more easily amenable to C&I focusing on policy or management process (input) indicators.

The consideration of third-party auditing as a possible optional extension to the C&I tool independent of certification requires an assessment of: 1) the benefit or value from using the C&I results for supporting third-party auditing; 2) the appropriate scale of application; and 3) the feasibility of implementing such a program. The discussion of the potential compatibility of these tools is just beginning and because there are significant policy implications, the following sections present a series of discussion points or questions to help further exploration of these topics.

What is the benefit or value of third-party auditing of public lands?

The primary benefit of independent verification is improved credibility. Related discussion questions include:

- Are there other benefits from third-party auditing?
- Does third-party auditing have a specific benefit at some scales (e.g., national, regional, local) versus others?
- Would credibility still be attained if the auditor worked with Forest Service constructed reference values/standards, or Forest Service collected data, or do they need to be involved in those functions as well?
- What kind of "auditor" would most improve credibility?
- If the public is involved in a fully collaborative approach to sustainability monitoring, is an external, third-party auditor still needed?
- What are the full costs of third-party auditing (in a cost-benefit relationship)?

What is the appropriate scale of application?

Sustainability is a multiscaled issue with different questions and considerations pertinent at specific scales. Related discussion questions include"

- At the national scale, if the focus of C&I is on the policy and institutional structures for sustainable forest management, can third-party auditing be of value?
- Is third-party auditing appropriate at subnational scales (e.g., States, regions, ecoregions); and if so, what are the sets of subnational management processes that should be considered?
- Can third-party auditing at the operational level be applied across multiownership jurisdictions (e.g., as is the intent of the approach in the LUCID Project)?

How feasible is a third-party auditing extension to C&I monitoring?

Third-party auditing has for the most part been limited in application to auditing indicators established to examine management performance. Related discussion questions include"

- Is third-party auditing compatible with an outcome-based approach to sustainability monitoring or only with implementation (management performance) monitoring?
- If so, and if outcome based measures are perceived as very valuable by forest management, is it useful to develop a paired system of implementation indicators for each outcome indicator?
- Or can third-party auditing be adapted to work with outcome-based measures?
- If third-party auditing can focus on outcome-based measures, what are they auditing: data accuracy and sufficiency?
- Does third-party auditing require common standards or can they vary from place to place?

CHAPTER HIGHLIGHTS

- Forest-scale sustainability monitoring can provide both a process and a tool to help transform the concept of sustainability into "real outcomes on the ground" by engaging people in a dialogue about what they mean by sustainability.
- LUCID participants concluded that monitoring for FMU-scale sustainability is feasible and can make significant contributions to improving Forest Service management.
- Within an adaptive management context monitoring can be used both to help answer questions about the outcomes of management activities and to inform the next phase or round of planning and management decision-making. The sustainability assessment becomes the core, the essential feedback loop, of managing for sustainability.
- FMU-scale sustainability monitoring is recommended as the core of forest plan monitoring activities. Specifically, FMU-scale sustainability monitoring can be used:
    - To form the core of forest plan monitoring activities.
    - Perform an analysis of existing system conditions as preparation for forest plan revision;
    - As a common set of criteria and indicators to compare alternative options on equal footing and with a common language;
    - For periodic assessment of the state of systems.
    - To facilitate dialogue and engage collaborators in a discussion of a relative assessment of sustainability;
    - To provide a trigger or early warning of the need for change in the management plan or for more detailed analysis;
    - To provide higher consistency in monitoring activities from forest to forest to facilitate understanding amongst the public; and
    - To organize and contribute to our understanding of sustainability at other spatial scales.
- LUCID participants noted that the tool and techniques have application on a daily basis at a range of scales. At the project level it provides a context and a frame of reference and is an entry point to discuss and reveal values.
- Building relationships between sustainability efforts across ideas, approaches and temporal and spatial scales is an important part of an overall strategy for improving management of sustainable systems at multiple scales.
- Examination of the relationships between FMU-scale sustainability monitoring and other scale initiatives requires consideration of: the nature of human values and the role of communities of place and communities of interest in forming our values; the nature of living systems and the inherent variability in their form and expression; and the methodological challenges associated with data integrity, sampling, and aggregation.
- Criteria and indicators and forest certification are two different but potentially complementary tools that have been developed to address the issues of sustainability. The choice of which tool to use will depend largely on the management focus or objectives and the match with what the tool can provide.
- The intent of an independent verification system is to provide a neutral assessment of the validity of a claim with a perceived benefit of improved credibility.
- The potential for third-party auditing to serve as an extension to the C&I tool independent of certification requires an assessment of: 1) the benefit or value from using the C&I results for supporting third-party auditing; 2) the appropriate scale of application; and 3) the feasibility of implementing such a program.

Chapter 15.

Implementation: Recommendations and Conclusions

The Value and Utility of FMU-Scale Sustainability Monitoring 251

➡ *Summarizes the value and utility of FMU-scale sustainability monitoring from the perspective of LUCID participants.*

Strategic Implementation Issues 253

➡ *Discusses strategic implementation issues and recommendations regarding the products and process of FMU- scale sustainability monitoring.*

Tactical Implementation Issues 261

➡ *Presents tactical implementation issues including a revised process for FMU-scale sustainability monitoring and discusses implementation feasibility.*

Research Recommendations 269

➡ *Presents a series of recommendations for further research including research on protocols, analytical techniques, and reference values.*

Conclusions 272

➡ *Highlights some of the key messages and lessons learned through the LUCID Project.*

> "[N]ational advancement towards sustainable forest management rests largely with actions that are carried out at the local level. If these local actions are to be assessed it will require indicators that are particularly suited to local needs. In other words, the need for local level indicators arose not just out of a 'top-down' imposition of a particular framework, but because 'bottom-up' reporting is absolutely essential to the whole effort of demonstrating progress at any scale."
> *(Canadian Model Forest Program 2000)*

The purpose of the LUCID Project was to test the feasibility of monitoring and assessing sustainable systems at the forest management unit scale. Implicit within the purpose was the intent of developing a mechanism to provide forest managers and collaborators with feedback on the state of ecological, social, and economic systems that would assist their planning and management.

Through this process LUCID participants identified a suite of products and a process for FMU-scale sustainability monitoring, discussed its value and feasibility, examined the relationship between monitoring at multiple scales, identified issues in need of further development and research, and examined the issues of implementation.

This chapter summarizes key conclusions for the study from both strategic and tactical perspectives. The first part highlights the value and utility of FMU-scale sustainability monitoring. Part two focuses on strategic implementation issues and recommendations. The third part focuses on tactical implementation issues. Part four focuses on research recommendations.

THE VALUE AND UTILITY OF FMU-SCALE SUSTAINABILITY MONITORING

LUCID team members and LUCID forest supervisors concluded that, based on their experience, FMU-scale sustainability monitoring had great value and should be done. The initial intent of FMU-scale sustainability monitoring was that it could be used to help provide forest managers and collaborators with feedback that could be used to monitor and improve Forest Land Management Plans; to enhance collaboration between national forests and other governmental agencies; and to relate forest plan outcomes with regional and national sustainability trends.

At the outset of the test, LUCID teams identified three broad potential benefits for participation: 1) an overall improvement to management; 2) stronger use and relationships between inventory, monitoring, and data management; and 3) improved collaboration. As experience with and understanding of FMU-scale sustainability monitoring grew, LUCID participants and LUCID forest supervisors expanded upon their reasons and rationale for the utility and value of such a process.

> *"The Allegheny National Forest is moving towards Plan revision. We want to get involved in something that will help move us towards that revision—both a methods and systems approach—and start communicating with others."*
> *(Kevin Elliott, Forest Supervisor, Allegheny National Forest)*

Valuable Information within an Adaptive Management Approach

LUCID forest supervisors and their teams have found that FMU-scale sustainability monitoring and assessment can provide valuable information for forest planning and management.

Specifically, sustainability monitoring can be used to:

- Conduct an assessment as part of the process of analyzing the management situation;
- Help prioritize and focus forest monitoring efforts;

- Help identify priority actions for management and research; and
- Emphasize the relationship of the forest to the surrounding ecological, socioeconomic contexts.

The systems-based framework and products of sustainability monitoring provide information that is more readily incorporated into management because they offer "a concise picture and cognitive tool to facilitate better understanding of the inter-relationships between the ecological, social, and economic systems" (Ottawa National Forest).

As part of the tool set used for forest plan revision, sustainability monitoring can help identify issues that will become critical when completing the information needs assessment. The common suite of C&I can be used to facilitate consistent comparisons of alternatives to examine interactions and to assess trade-offs in a way that addresses diverse concerns and values. Over time, monitoring and assessment can be used to identify areas that need management attention. Adjusting management area goals or revisiting desired system conditions would be two kinds of adaptations recommended from a sustainability analysis.

Because FMU-scale sustainability monitoring results in a more coherent monitoring program that is readily customizable, LUCID participants thought it would be a tool that was more readily used by managers and could help prioritize projects, conduct out-year planning and budgeting, facilitate collaboration opportunities, and make reporting much easier. Current monitoring initiatives and approaches were not perceived as providing this.

"Every forest has a story. Forest-scale sustainability monitoring needs to have enough of a common framework to tell the stories at each scale of the organization. In the end, the vital few Criteria and Indicators must be able to help us tell the stories."
(Gary Larsen, Forest Supervisor, Mount Hood National Forest)

Identifying Critical Issues

Beyond providing a broad-based feedback loop for management, FMU-scale sustainability monitoring was identified as a valuable tool to help identify critical issues for further examination of management attention. Sustainability monitoring can be used to flag system elements or areas spatially that need further investigation. When concerns are flagged through the comparison of current data values against reference values, it may lead to more detailed analysis of supporting and supplementary information about the concern area; it may focus management attention in watching trends more carefully over time; and it may result in a reexamination of the model assumptions, data issues, or appropriateness of the reference values.

"The Blue Mountains Province is a disturbance driven ecosystem. We wanted to get a handle on the systems approach to sustainability to help us understand this large, three-forest area."
(John Schuyler, Deputy Forest Supervisor, Wallowa-Whitman National Forest)

The systems-framework approach differs from many other monitoring initiatives that are issues-based. Issues-based monitoring programs (for example, forest pest monitoring) may provide very specific information and detail on known and priority management concerns. The systems-framework provides more of a gross safety net and can provide the explanatory structure for understanding issues. While it does not do detailed issue

"The Modoc National Forest is interested in linking to other organizations (e.g., BLM, conservation district) and initiatives such as watershed demonstration projects. All ownerships are looking for something meaningful that works across ecological, social, and economic systems; and multiple ownerships are crying out for a common language to talk to one another."
(Dan Chisholm, Forest Supervisor, Modoc National Forest)

analysis, it does provide an overall assessment of the state of the system and provides opportunities to assure that all parts are being considered. This broad-based approach can be useful not only in helping to identify emerging management issues but also to look comprehensively at the cascading implications of the interactions between monitoring elements.

Providing a Forum for Discourse

Sustainability monitoring provides a forum for discourse with the public about their values of our stewardship of national forests.

Criteria and indicators and the systems framework provide a basis for developing a common language to talk about the diverse values people hold for sustainability. And although there will still be intense conflicts over competing values that need resolution, the framework and language can provide a common basis around which people can compare alternatives and discuss desired future system conditions. As such, sustainability monitoring provides a firm basis for discussing the public values about sustainability (a relative assessment of sustainability rather than an absolute measure of sustainability).

STRATEGIC IMPLEMENTATION ISSUES

Strategic implementation issues include the value and utility of FMU-scale sustainability monitoring, feasibility issues, and the role and place of FMU-scale sustainability monitoring related to other initiatives and processes. The section starts with a summary of the key features of FMU-scale sustainability monitoring.

Key Features of FMU-Scale Sustainability Monitoring

Systems Approach as a Common Guiding Framework

The LUCID Project demonstrates that **a systems approach provides an effective organizing framework to develop a sustainability-monitoring program for the forest**. Specifically, the approach:

1) Leads to a richer and more integrated understanding of ecological, social, and economic systems;
2) Can help identify, define, and organize critical indicators and measures for monitoring;
3) Serves as a conceptual basis for analysis and synthesis of monitoring data in order to assess the emergent properties of systems and the interrelationships between the ecological, social, and economic spheres; and
4) Can be applied consistently at the FMU scale.

Adoption and use of this common systems framework, defined by the principles and criteria, can provide a consistent organizational approach to understanding, monitoring, and assessing sustainability at the FMU scale.

A Core Suite of Criteria and Indicators

There is a core suite of C&I recommended for application across the national forest system for FMU-scale sustainability monitoring.

The eight national forests representing a range of different ecological, social, and economic conditions identified a relatively common set of principles, criteria, and indicators.

The systems-based framework of three principles and 16 criteria is recommended to ensure consistency. A suite of 58 indicators is strongly recommended for use on all forests; however, some adaptation will be necessary to ensure that the indicators meet the full range of conditions on each national forests. We would anticipate that some forests may want to enhance the core indicators with supplementary indicators focusing on specific system elements or functions of concern.

Measures were developed and tested for each indicator. Where standardized measurement protocols were known and available at the right scale that could be used to verify the indicators, these were incorporated in the final C&I. There are 119 recommended measures within the core suite of C&I along with additional suggested proxy and supplementary measures.

> *"Working towards sustainability is a key role for the national forest system, and the Ottawa National Forest needs to take a leadership role in this endeavor." (Phyllis Green, Forest Supervisor, Ottawa National Forest)*

In areas where we have familiarity and experience in monitoring (predominantly in ecological systems and including some aspects of economic systems), identifying common measures among forests was relatively easy. In areas such as social systems where our understanding of the connections between the national forests and the broader social system is less clear and where the Forest Service has less experience in monitoring, it was more difficult to identify common measures.

There are a number of initiatives associated with the development and refinement of monitoring protocols at a range of spatial scales that are currently in progress. The choice of measures needs to remain flexible enough such that forests can work from this growing base of knowledge and select those appropriate to their particular conditions.

Presented in list form, measures, like indicators, are worded broadly to ensure applicability across the range of different conditions. A detailed database of definitions and descriptions of all elements (principles through measures) in the final suite of C&I is provided in this report (Appendix 9). The process of identifying possible data sources for these measures was started through the work of the six forest teams and has been supplemented by initial examination of potential overlap between these measures and corporate data sources (e.g., NRIS). **Additional work and discussions are needed to ensure the best fit between corporate data sources and repositories and those required for FMU-scale sustainability monitoring and expand on the material within the database.**

Flexibility in selection, measurement, and assessment is needed to make the process most useful to each national forests. The development of indicators and measures of sustainability is a new field and should continue to be iterative in nature. The approach to FMU-scale sustainability monitoring should be flexible enough to incorporate suggested improvements. Maintaining a systems-framework will provide a common organizing structure over time. **An adaptive learning process to capture, test, and share these improvements and facilitate consistent approaches where appropriate should be developed.**

Assessing Sustainability: Approaches to Analysis and Synthesis.

The systems framework sets in place a common conceptual approach that can be used to frame analysis and synthesis of concepts. The intention is that people are engaged in a relative assessment of sustainability rather than an absolute sustainability determination. Analytical approaches and tools, such as those used during the LUCID Project, should be used to examine not only the status of individual monitoring elements but also to begin to synthesize the interrelationships between systems.

Analytical tools that are built on expert-systems, are object-oriented, can be organized and built to represent the full complexity of the interrelationships and emergent properties of systems; have the capacity to work with a range of reference values, and are capable of working with data from multiple spatial scales are very valuable. **We recommend that efforts be made to enhance existing tools to include all of the most desirable features in a way that is compatible with USDA Forest Service corporate software.** However, no one tool can provide all answers; and there is a research need to improve the science of assessing sustainability. While some standardization in analytical approaches and tools is useful, additional analytical tools and techniques will be required to fully analyze and synthesize sustainability monitoring information.

The Process of Monitoring: Learning About Sustainability

One of the key findings of the LUCID Project on sustainability monitoring was that the process of engaging the national forests staff and collaborators in a dialogue about sustainability and sustainability monitoring was invaluable. The steps involved in the process of developing and implementing a monitoring program for sustainability assessment at the FMU scale emerged as important as more tangible products such as a list of criteria and indicators. An outline set of revised and streamlined key steps are provided later in this chapter. **We recommend that FMU-scale sustainability monitoring should be linked to the new Planning Rule business requirements models.** The intent is that the revised procedures will

> *"My motivation on the Mt. Hood National Forest is based on a personal commitment to sustainability that is shared with other forest supervisors who participated in the project. I wanted to work on a sustainability process that is bottom-up, not just top-down. The Mt. Hood is also a disturbance-driven system but in this case the disturbance is predominantly related to social systems. The Hood's interest was in providing a test-bed to expand the social concepts of sustainability and broaden beyond the Forest Service traditional strengths of ecology. This is especially relevant since we are managing the forest in a greater ecosystem context."*
> *(Gary Larsen, Forest Supervisor, Mt. Hood National Forest)*

facilitate a process where interdisciplinary and collaborative teams:

- Focus attention on the values of sustainability;
  - Build understanding of attributes and functions of sustainable systems;
  - Help clarify Forest Service and public values and understand perspectives on issues and solutions;
  - Develop models of how system elements and issues are integrated;
  - Identify desired future system conditions;
  - Monitor current conditions;
- Engage people in a dialogue about a relative assessment of sustainability; and
- Provide useful feedback, in a timely way, to management.

We also recommend that through the implementation process a "lessons learned" database of case study experiences be assembled that parallels these key steps.

The Feasibility of FMU-Scale Sustainability Monitoring

Is FMU-scale sustainability monitoring feasible to implement? Aspects of implementation including complexity, cost, consistency and flexibility are critical aspects of examining feasibility. Clearly, there are reasons to question the agency's ability to conduct sustainability monitoring, among them: the resources currently associated with monitoring activities, many competing issues and priorities, a lack of personnel with the appropriate skill sets in the social and economic disciplines. **But the value and benefits from sustainability monitoring to on-the-ground management suggest we should begin and grow into the opportunity**.

The feasibility of FMU-scale sustainability monitoring relies on:

- Strong business requirements demonstrating the need and priority for such an initiative;
- Embedding sustainability monitoring within existing management processes;
- A reexamination of existing monitoring priorities;
- An elimination of redundancies;
- Forging strong connections with other related initiatives and programs; and
- More reliance on partnerships and effective collaboration to supplement the Forest Service's abilities.

As a pilot test process, the LUCID Project involved a series of detailed steps fraught with substantial uncertainty and complexity. In the course of developing and testing a suite of criteria and indicators and analysis methods, LUCID participants spent much of their time identifying and developing the key parts of a process for sustainability monitoring. Although grappling with the issues of sustainability monitoring and assessment will remain complex, the process that evolved through the testing process does not have the same degree of implementation complexity as experienced during the pilot effort (tactical implementation issues are discussed in more detail in the next section of this chapter). LUCID participants felt that FMU-scale sustainability monitoring was feasible for implementation at the field level.

From a strategic or policy perspective a number of issues affecting feasibility need resolution:

- Identifying the programmatic place of sustainability monitoring in the forest management process. Does sustainability monitoring become central to forest plan monitoring or is it supplementary to it?

- What activities (monitoring or otherwise) will sustainability monitoring replace? Where are the redundancies?
- How will sustainability monitoring at the FMU scale be funded? Is there funding for monitoring core items or does funding support rely on tying individual monitoring items to program and project funding?
- How can efficiencies be gained by corporate support and provision of data and a data repository for FMU-scale monitoring and for enhancing existing regional or national monitoring efforts such that they provide the right data at the appropriate resolution?

Clarifying the true costs and resources required for implementation require the resolution of these and other issues. The potential feasibility of implementing this scale of sustainability monitoring also depends on the current status of inventory and monitoring activities on national forests. LUCID forest teams were unable to completely enumerate the overlap between the suggested monitoring elements and existing monitoring activities. Even so, they did estimate the overlap between their draft list of elements and existing monitoring efforts (in all cases the forests' lists of C&I were larger than the final core suite). The extent of overlap ranged from a low of approximately 15 to 20 percent to a high of approximately 70 percent.

In addition, the experience of the national forests involved in the Southwest Idaho Ecogroup Forest Plan revision (Chapter 14) who designed the monitoring portion of their plan with a systems approach suggests that existing forest plan monitoring can be reorganized to work within a systems framework and can be used to synthesize related items and highlight missing elements.

For some forests there may be a great deal of adjustment and modification required while for others transition to a systems-based approach to monitoring may simply mean adopting a new framework for thinking. **Adopting a consistent framework would have the added benefit in this case of decreasing the inconsistencies between forests and improving understanding and transparency for the public**.

The readiness and willingness of potential partners and collaborators to participate is also a key feasibility issue. In many locations State and local governments, industry associations, and community and nongovernmental organizations have been very active in sustainability issues while at the field level the Forest Service has been less active. Where FMU-scale sustainability monitoring is done in a collaborative manner involving the public and other land managers it will require additional time. This time is required not only to develop relationships and come to common agreement but also in actual data collection. A representative from Boise Cascade Industries involved in managing forest certification initiatives notes that the issue of working in larger land areas (particularly if they cross multiple ownerships) is not typically a lack of data richness but one of data compatibility (Holt 2001).

A New Approach and Framework to Discuss Values

"Forest Service folks tend to talk about management actions, conditions, and products and find it difficult to talk in terms of values, choices (budgets), and effects (services) of our management actions. We can adopt some exercises to better understand and reveal the relationships between our values and the ecological services and products that will result, even if only in qualitative terms. This need not be a dramatic shift in management, but in how we describe our management. After a bit of practice, we would likely be better system thinkers/integrators (the primary product of our LUCID experience) and better interpreters of our actions and the values they represent. This might set us up for more effectively reviewing or reconsidering our own values, deciding they are appropriate, or considering new values." (Ottawa National Forest Team)

Identifying the most parsimonious set of criteria and indicators is a critical issue. As discussed in Chapter 8, the core set of 16 criteria and 58 indicators is on par with most other C&I initiatives. The suite of C&I has undergone a series of revisions and reductions to try and focus on the smallest set of indicators that capture the breadth of systems. Much of the time associated with a sustainability-monitoring program is in its establishment after which the frequency of monitoring for each element will vary.

Monitoring frequency and effort, associated with issues of accuracy and precision are implementation issues that will need to be determined in a flexible fashion.

Consistency and Flexibility

Consistency and flexibility have permeated the discussions within the report. Consistency is valuable in that it can help improve understanding, facilitate transparency, comparisons and potentially accountability, and result in cost savings associated with efficiencies in implementation. In turn, flexibility can allow for adaptation necessary for different contexts and can lead to a greater sense of ownership, enthusiasm, and creativity.

Traditionally, consistency has been championed by those advocating centralized top-down approaches and flexibility by those advocating decentralized field-based approaches. We suggest an alternative playing field that gains synergistic advantage by using a common conceptual (systems) framework while achieving maximum learning and innovation through mainstreaming of these concepts. Within the context of FMU-scale sustainability monitoring aspects of both consistency and flexibility are highly desirable.

The products and process of sustainability monitoring have been developed with a mixed approach that has attempted to incorporate the advantages of both approaches and minimize the disadvantages. LUCID forest supervisors and LUCID participants who had been involved in other inventory, monitoring, and planning processes (e.g., regional monitoring efforts such as ICBEMP, SPAM, and the FORPLAN) called for the need for flexibility in implementation. **LUCID participants recommended consistent application of a common framework (principles and criteria) with increasing degrees of flexibility as one moves to finer degrees of implementation. This allows the framework to be contextualized to meet field needs and adapted to help tell the unique stories of each forest** (Figure 49).

Beyond the common framework and C&I elements, participants called for a balance between providing consistent guidance in the process of sustainability monitoring and assessment and flexibility. Given the value associated with the learning process in developing a sustainability-monitoring program and engaging in a collaborative dialogue about sustainability, participants feared that if the process itself was so institutionalized and formalized they might lose the value of the learning process. **Instead, participants called for nationally supported technical assistance to help coordinate and facilitate the learning process and to provide consistency in implementation.**

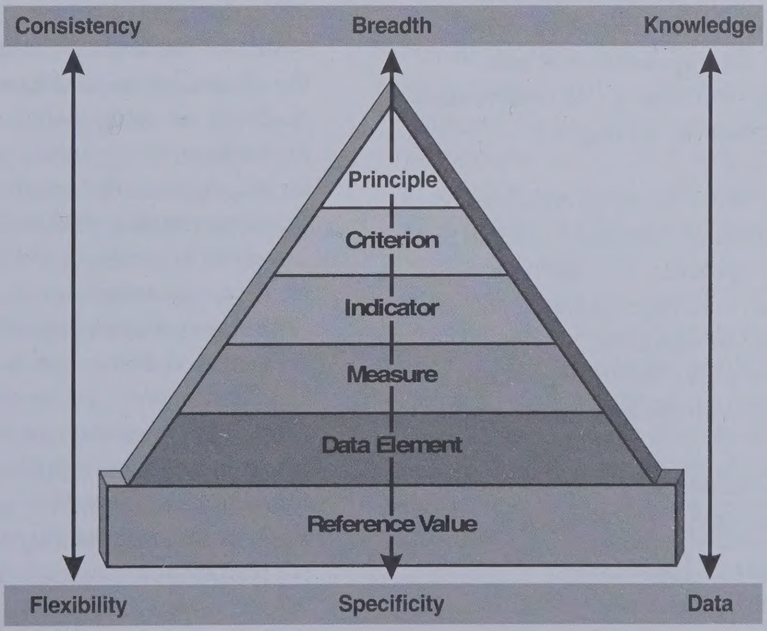


Figure 49. Consistency and Flexibility Issues Associated with Criteria and Indicatorsl

There are other more detailed aspects of FMU-scale sustainability monitoring that could benefit from a consistent approach. The requirements and needs for measures, reference values, and data were not specified prior to the LUCID Project. Although many other initiatives and institutions at a range of scales had been involved in C&I processes, the system-based approach to sustainability monitoring at the FMU scale was unique. Additionally, most other C&I initiatives had only begun to specify possible measures and discussions of reference values were almost non-existent.

LUCID forest teams spent a great deal of their time identifying possible measures and reference values as well as pursuing possible data sources, and all noted that much work still remains in these areas. A central conclusion of the Forest's efforts was the need for flexibility to adapt measures and reference values, and ultimately then the data requirements, to the unique contexts of the forest. To the extent that most forests will likely require some common and basic data elements for sustainability monitoring, there is great benefit to be achieved from consistent use of common data sources. Given the scope of the LUCID Project and the rapidly evolving work of those involved in developing corporate measurement protocols or data sources and repositories (e.g., the IMIT Protocol Teams, the Planning Rule Directives Teams, and NRIS), only preliminary overlaps have been identified. **There is a strong need to integrate these various initiatives and work together to develop an approach that can facilitate the supply and storage of information and data that are suited to a range of multiscaled questions.**

At the analytical level issues of consistency and flexibility also abound. Chapter 11 discusses potential areas for consistency and the need for flexibility in the analytical approaches, reporting requirements, and use of analytical tools. **Technical assistance is needed to help resolve and enhance analytical tools and approaches.**

Sustainability Monitoring as an Addition, Supplement, or Replacement

The role and place of FMU-scale sustainability monitoring related to other initiatives and processes is a key strategic implementation topic. Three related questions posed throughout the LUCID Project are:

1) If sustainability monitoring is useful, can it replace what we are doing?
2) Should sustainability monitoring be an addition or supplement to existing monitoring, or should this replace forest plan monitoring?
3) Can a systems-based sustainability-monitoring program fit with inventorying, monitoring, and data-management initiatives that are functionally organized and if so, where are the overlaps and efficiencies?

FMU-Scale Sustainability Monitoring and Existing Forest Plan Monitoring

Forest Service monitoring activities include implementation monitoring, effectiveness monitoring, and validation monitoring. For the most part, the current forest plan monitoring initiatives focus on implementation monitoring. FMU-scale sustainability monitoring focuses on outcome-oriented indicators to examine the state of ecological, social, and economic systems. Within an adaptive management context, **FMU-scale sustainability monitoring is recommended as the core mechanism to provide feedback on forest management.**

If FMU-scale sustainability monitoring were to become the core of forest plan monitoring, as implemented in a pilot approach by the Southwest Idaho Ecogroup, it would focus the monitoring efforts on an assessment of the state of forest systems. There are definite distinctions between the short-term requirements for management feedback on actions often best assessed by input or management process indicators and the long-term requirements for monitoring outcomes. **Implementation monitoring will still be required in order to track actual actions and tie it to outcomes, but it can be organized within a systems context** to facilitate the linkages between short-term and long-term outcomes.

Alternatively, forest plan monitoring could remain as is and the sustainability-monitoring program could be supplemental in nature, perhaps timed to coincide with forest plan revision. If FMU-scale sustainability monitoring is supplemental to existing monitoring, to be most effective clear linkages and feedback mechanisms between the two would be needed. For many forests there would be significant redundancies in monitoring activities that would be inefficient and may lead to the marginalization of one monitoring activity over another. Under this scenario it is quite likely that FMU-scale sustainability monitoring would be an afterthought activity and the value of the systems approach to understanding and managing systems would be less likely to be realized throughout forest planning and management.

Relationships Between Monitoring Initiatives

Earlier sections of this report (see, for example, Chapter 9) discuss a sample of ongoing initiatives related to inventory and monitoring at a range of spatial scales (for example, the NRIS common database storage system, the IMIT protocol teams, the Planning Rule Directives groups, and existing corporate I&M systems such as FIA and FHM). Even when the focus is limited to those initiatives at the spatial scales most applicable to FMU-scale sustainability monitoring there are a significant number of initiatives. Each initiative in itself can make a valuable contribution to monitoring in general and to FMU-scale sustainability monitoring specifically. IMIT protocol teams such as the Human Dimensions, Terrestrial and Wilderness groups are helping to identify standardized suites of measurement protocols applicable to those focus areas. **Improved standardized measurement protocols to address questions at the FMU scale will be highly beneficial to sustainability monitoring**. The related forest plan directives teams such as Soils are focusing, among other things, on the development of methods to construct reference values (standards). **As LUCID forest teams noted, any assistance that can be given on the means to construct more meaningful reference values is definitely needed.**

However, a forest supervisor or monitoring coordinator trying to navigate through the range of these initiatives can quickly run into process gridlock that results in a potential resource drain. To the extent that there is a continued focus on functionalism where soils, wilderness, human dimensions, terrestrial, aquatic and other components are separated, the problems multiply exponentially. Managers or monitoring coordinators could be forced to participate in and assimilate a series of protocols; and in the end while the databases may be integrated the knowledge and understanding of the ecological, social, and economic systems (either independently or together) will not be.

The suggestion is not that we are trying to lose the parts and the expertise that are necessarily focused on improving inventorying, monitoring and database management issues associated with each. Rather we suggest that without a common framework and process to unify these initiatives forest monitoring will continue to be characterized by a shotgun pattern consisting of independent and unique data elements. For a forest manager trying to engage personnel and collaborators in continuing on the quest for sustainability the need is not specifically for data, but for useable knowledge. FMU-scale sustainability monitoring provides the core information and a framework and organizing system to integrate the details of the different parts and to understand whole system attributes. Functional or disciplinary adjuncts will always be useful to add detail on specific structures or processes and to explore tangents.

For initiatives beyond the FMU spatial scale, the purposes and objectives will vary. Given the different purposes and audiences, to the extent possible, relationships should be built between these initiatives. Where feasible, monitoring at one scale can inform monitoring at other scales; and where the same piece of data can be useful at multiple scales, mechanisms for sharing this data should be established. As discussed in Chapter 14, developing relationships between these multiscaled initiatives, while it may be strongly desired, is quite complex. The first step is to truly examine and understand the purpose, nature, and organization of the different initiatives and then to develop linkages within the contexts of scale, systems, and data-integration implications.

STRATEGIC IMPLEMENTATION HIGHLIGHTS

SYSTEMS FRAMEWORK

☑ The systems-based framework of three principles and 16 criteria is recommended.
☑ The systems framework sets in place a common conceptual approach that can be used to frame analysis and synthesis of concepts.
☑ FMU-scale sustainability monitoring is recommended as the core mechanism to provide feedback on forest management.
☑ Implementation monitoring will still be required for tracking actual actions and tie implementation monitoring to outcomes but it can be organized within a systems context.
☑ Adopting a consistent framework would have the added benefit of decreasing the inconsistencies between forests and improving understanding and transparency for the public.
☑ A core C&I is recommended for application across the national forest system for FMU-scale sustainability monitoring.

PROCEDURAL AND IMPLEMENTATION SUPPORT

☑ FMU-scale sustainability monitoring should be linked to the new Planning Rule business requirements models.
☑ Through the implementation process a "lessons learned" database of case study experiences should be assembled.
☑ Participants called for nationally supported technical assistance to help coordinate and facilitate the learning process and to provide consistency in implementation. An adaptive learning process that could help capture, test, and share improvements and facilitate consistent approaches should be developed.

MONITORING PROTOCOLS AND TECHNICAL TOOLS

☑ Existing tools for analysis and synthesis should be enhanced to include all of the most desirable features in a way that is compatible with USDA Forest Service corporate software.
☑ Monitoring frequency and effort, associated with accuracy and precision are implementation issues that will need to be determined in a flexible fashion.
☑ There is a strong need to integrate these various inventorying, monitoring and data-management initiatives and work together to develop an approach that can facilitate the supply and storage of information and data that are suited to a range of multiscaled questions.
☑ Additional work and discussions are needed to ensure the best fit between corporate data sources and repositories and those required for FMU-scale sustainability monitoring.
☑ Technical assistance is needed to help resolve and enhance analytical tools and approaches.
☑ Improved standardized measurement protocols to address questions at the FMU scale will be highly beneficial to sustainability monitoring.

TACTICAL IMPLEMENTATION ISSUES

A Vision for Implementation

In their evaluation of the LUCID Project, participants concluded that the **process** of developing and implementing a sustainability monitoring program became as valuable as producing the monitoring **products** or results themselves. **Consequently, the goals of implementation should be not just to ensure a set of nationally consistent and efficient products but also an implementation approach that promotes and facilitates the dialogue and learning within and between national forests staff and the public.**

This section presents a brief summary of a revised process for FMU-scale sustainability monitoring. This is followed by a discussion of some of the necessary considerations for implementation.

A Revised Process for FMU-Scale Sustainability Monitoring

The six forest teams involved in the LUCID Project participated in a common methodological approach to developing a sustainability-monitoring program. Although some of the steps were specific to the pilot nature of the test, many of the steps have application for implementation. During the evaluation phase of the project, forest teams highlighted key steps and suggested additions and revisions. Throughout this report the various chapters present the experiences and process recommendations for each of these steps. Based on the experiences of the forest teams, a revised set of steps was developed.

Figure 50 presents a flowchart of the key steps identified for sustainability monitoring at the forest management scale. The flowchart has two main pathways with the primary one on the core procedures and the secondary pathway profiling needed support tasks. This supporting pathway details tasks related to preparation for each stage and for forging connections with other initiatives and resource people. Additional work is needed to further develop and expand on this methodology could best be achieved by developing a business requirements model.

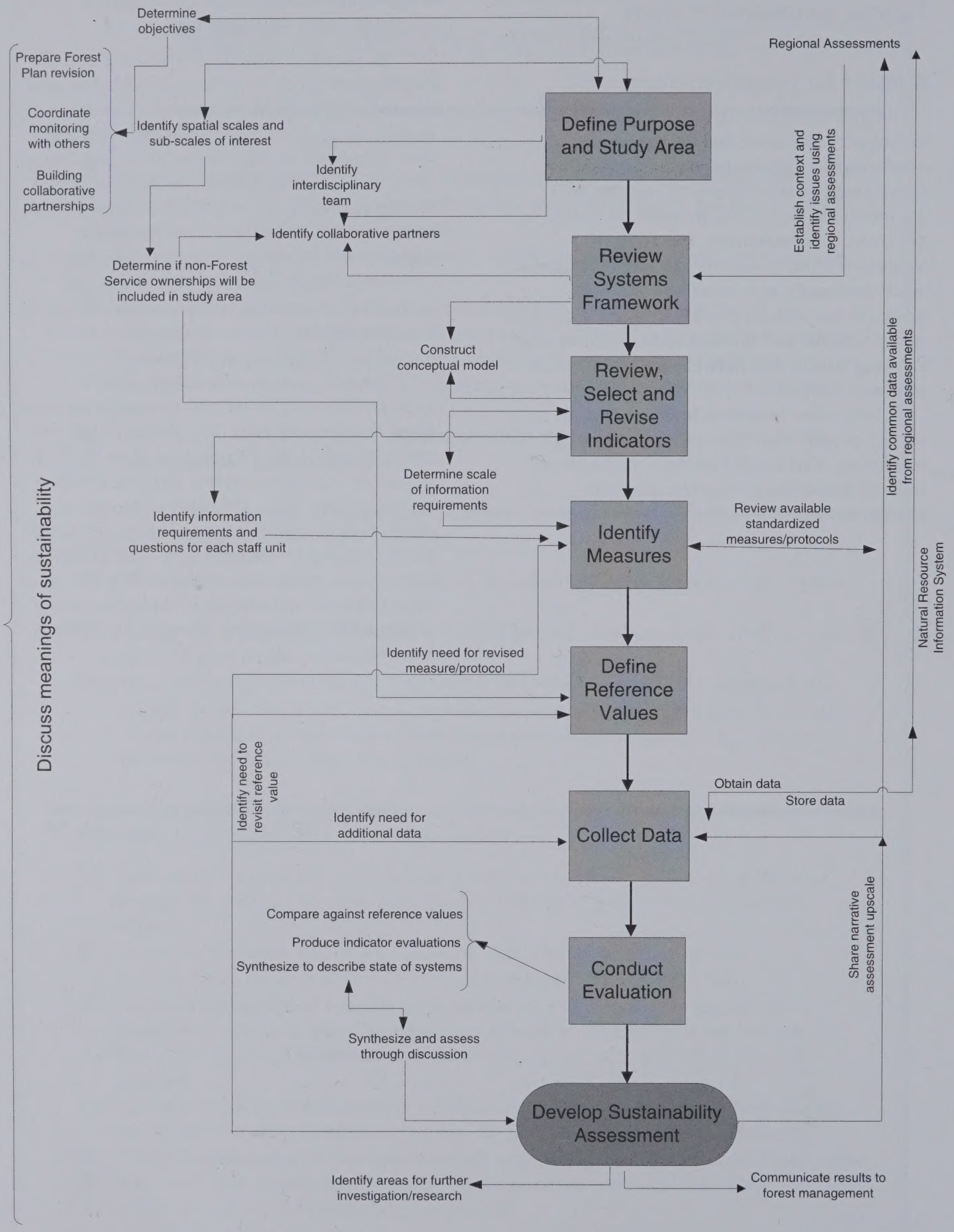

Determine objectives
Regional Assessments
Prepare Forest Plan revision
Coordinate monitoring with others
Building collaborative partnerships
Identify spatial scales and sub-scales of interest
Define Purpose and Study Area
Establish context and identify issues using regional assessments
Identify interdisciplinary team
Identify collaborative partners
Determine if non-Forest Service ownerships will be included in study area
Review Systems Framework
Construct conceptual model
Review, Select and Revise Indicators
Identify common data available from regional assessments
Determine scale of information requirements
Identify information requirements and questions for each staff unit
Identify Measures
Review available standardized measures/protocols
Natural Resource Information System
Discuss meanings of sustainability
Identify need for revised measure/protocol
Define Reference Values
Identify need to revisit reference value
Obtain data
Store data
Identify need for additional data
Collect Data
Compare against reference values
Produce indicator evaluations
Synthesize to describe state of systems
Conduct Evaluation
Share narrative assessment upscale
Synthesize and assess through discussion
Develop Sustainability Assessment
Identify areas for further investigation/research
Communicate results to forest management

Figure 50. Revised Process for FMU Scale Sustainability Monitoring

Resources Required for Implementation

Continuous Learning Process

LUCID forest teams and those involved in other monitoring programs have recognized the value of building on the experience of others and in benefiting from lessons learned. The desired goal for implementation is achieving a useful balance between consistency and flexibility. In the quest for consistency, the result is often a highly prescriptive process. A process that is very prescriptive and detailed often cannot be adapted to meet the specific requirements of the unique context. This is particularly problematic when the intent is to work collaboratively. Prescriptive processes tend also to be viewed as tasks instead as opportunities to be creative and learn jointly. However, if the process is recreated and completely revised each time not only will needed consistency be lost but the process will be very inefficient and the teams will not benefit from learning from the experience of others.

The challenge is to assist forests with implementation of a process to enable continuous learning. Based on the experience of the LUCID Project, we recommend two broad strategies. **The first, discussed in the previous section, involves establishing a core technical assistance group who can build a community of practice about sustainability monitoring.**

The second focuses on the development and enhancement of tools that can serve as interactive repositories of monitoring components (e.g., Indicator Resource Database) as well as means of documenting the experiences of forests in the implementation process. The intent is that the lessons learned and experiences of others are available in a just-in-time fashion since experience with the LUCID Projects shows that if forests have to actively track down that experience or retain it from an earlier review of methodology they are unlikely to do so.

The vision is that the basic process template described in Figure 48 be expanded with details on specific approaches associated with each major step provided and supplemented with a database of associated case study information profiling examples from the forests. Specific data management, analysis, synthesis and reporting tools (such as the LUCID Resource Database) would be linked into this tool. In addition, connections would be made to the business-planning model to ensure Planning Rule requirements were met. Much of the material for this tool comes from the LUCID Project report and individual forest experiences; it merely organizes them in a way to ensure that they are most useful to those undertaking the process. A key aspect to achieve the continuous learning goal; however, is to develop a mechanism by which forests can make contributions based on their experiences. The resulting tool is not just a static manual but rather becomes a living document that grows as the experiences grow. The Inventory and Monitoring Institute is currently initiating some of the steps required to implement such an approach.

The C&I resource database (Appendix 9) developed as part of the LUCID Project is one of the core components of the above tool set. In its current form it provides documentation on the forests' experiences; but it needs continued development, editing and enhancement. Consistent with the approach discussed above, we recommend that it be enhanced to allow continuous updating by forests and to reflect other aspects of implementation. Similar approaches have been developed to perform a mix of these functions including the web-enabled interactive Sustainable Communities Indicator Program (Environment Canada 2002) that includes recommendations for the process of establishing a sustainability-monitoring program as well as an indicator database and the CIFOR initiative, the Criteria and Indicator Modification and Adaptation Tool (CIMAT) and its associated Resource Database (CIFOR n.d.) program which guides users through the customization and adaptation of criteria and indicators of sustainable forest management.

Technical Assistance

Strong and nationally consistent technical assistance can help facilitate the implementation of FMU-scale sustainability monitoring creating efficiencies between forest efforts and improving consistency. The approach implemented by United States Agricultural Extension Agents that puts resource specialists in direct contact with practitioners suggests one possible model. A national technical assistance team can facilitate implementation such that the burden of answering global questions that will be faced by all forests does not fall to each individual forest. In a model similar to the NRIS strategy for implementation, the national team can provide leadership and consistency in program guidance, regional teams can provide regional guidance and specific assistance (e.g., socioeconomic skills supplementation) for forest implementation. The result is not only process efficiency but also potentially a more consistent approach. Specifically, a technical assistance team may be involved in tasks such as:

- Combining the results of sustainability monitoring and assessment into an adaptive learning process for the various levels of the organization;
- The identification of duplication and efficiencies of sustainability monitoring and other national forests monitoring requirements;
- Further development and guidance on measurement protocols, reference values, and data acquisition;
- Refinement of tools/methodologies to help integrate and present monitoring information;
- The development of collaborative mechanisms to intentionally create and share what we know about sustainability with partners;
- Assure scientific consistency; and
- Provide managerial leadership and coordination.

Team Composition

Chapter 4 presents a discussion and series of recommendations regarding team composition. **We recommend a forest team of approximately five people consisting of specialists from ecological, social, and economic disciplines along with a GIS analyst and a team leader**.

Given the collaborative requirements of the program, the team leader may be someone who has strong public information skills or interdisciplinary skills such as those often associated with forest planners. The team should be involved with the design of the monitoring program and should help to coordinate the associated monitoring activities, in particular the assessment phase.

Although this forest team will coordinate the initiative there should be frequent involvement and strong ties built between sustainability monitoring and forest management. Clear mechanisms should be established to ensure that all forest staff are aware of the initiative and available to assist both in monitoring activities as well in the analysis and interpretation of results.

Technical Support

Two areas where forests have a skills short-fall are the social and economic disciplines. During the LUCID Projects, two of the forest teams involved external collaborators from universities as a way of supplementing their skill sets; and the other forest teams borrowed from other forests or regional offices. Generally, however, all of the forest teams indicated that they needed additional assistance in these areas. The lack of access to individuals with socioeconomic skills is common across the national forests system.

The traditional staffing approach within the Forest Service has been to provide people with the needed skills on each forest; however, for socioeconomic skill sets this has never been achieved. Alternatively, **a group of specialists who have the needed skills could be assembled at a regional or national scale**. These specialists would have the technical knowledge to work with forest team members who have local knowledge of social and economic issues.

Additionally, **forests should be encouraged to continue the practice of developing collaborative partnerships with outside specialists** as was the experience of the Allegheny and Mt. Hood Forest Teams. Connecting regional or national human dimensions specialists together with forest staff and collaborative partners can provide a creative option for overcoming the skill limitations.

Providing access to technical specialist support in areas other than human dimensions is also suggested. Some LUCID forest teams were able to build relationships between regional office specialists and research staff but all indicated the need for additional work and cooperation in this area. **A network of research and regional office specialists could be built to support forest-scale sustainability monitoring initiatives**. Providing national guidance and support for the creation of this network would mean that individual forests would not have to recreate these networks each time.

Financial Resources Required

Sustainability monitoring provides a valuable feedback loop to ensure sustainable management. Like certification monitoring, sustainable monitoring is a cost-center; but it is the cost of doing the business of ensuring wise management. Monitoring becomes part of fulfilling a social contract that is a requirement of upholding the public trust and particularly relevant for public land managers. Indeed, the question of the cost might be better asked in the alternative form: what is the cost (the risk) of not monitoring for sustainability?

Estimating the costs for implementing an FMU-scale sustainable management program is difficult. The costs of the LUCID pilot tests were supported by funding from the Washington Office. forest team costs averaged $151,000 and ranged from $120,000 to $166,000. These costs, however, do not provide a reasonable basis for estimating implementation costs since they represent the costs of performing a research project that involved substantial time spent on developing tools and techniques, testing software and evaluating the utility of the tool. The pilot test costs also do not include the cost of data acquisition or factor in the cost of related tasks such as database management and storage, any supplemental collaboration, or reporting. Still, they provide some benchmark of the costs of doing the strategy portion of monitoring.

Costs are associated not only with the direct costs of the person days, effort, and skills required for accomplishing the activities but also the indirect costs. For monitoring programs the indirect costs include such areas as training, skill development and enhancement, investments in research and development, indirect costs of acquiring data, the program management or organization of the monitoring program. Indeed it is likely that the indirect costs for such a monitoring program may represent a significant portion of the expense.

We recommend two further steps be taken to help develop more realistic cost estimates. The first, discussed earlier in this section, calls for **linkage to the new Planning Rule business requirements models.** Business modeling forms the basis for calculating most other costs within the Forest Service, and such an analysis could form a reasonable basis for estimating costs.

Costs of a Monitoring Strategy

The 2002 Planning Cost Study provides preliminary results of the total costs to the government for implementing the proposed Planning Rule. Nine sample national forests provided estimate details in different cost centers based on the proposed Planning Rule language.

The monitoring cost center covers the costs of preparing a monitoring strategy as part of the forest plan including activities such as developing methods, including monitoring provisions in the Plan, the costs of defining and storing data, and coordinating with others. Preliminary cost estimates ranged from $100,000 to $800,000 with a most probable estimate of $400,000. These cost estimates are based only on the information and direction provided within the Planning Rule; thus, we do not suggest they represent the costs of FMU-scale sustainability monitoring. To estimate those, a detailed business model founded in the Planning Rule directives for forest plan monitoring is required. However, these cost estimates do provide a benchmark for consideration.

Secondly, we **recommend that in keeping with a phased implementation approach, costs are tracked carefully for forests implementing FMU-scale sustainability monitoring.**

Timing Considerations

FMU-scale sustainability monitoring can serve as a primary feedback mechanism for forest management within an adaptive management context. Although sustainability monitoring can be of benefit in a number of stages from the analysis of operational and site-level planning to broader strategies of communication and reporting, the program has its strongest tie to forest planning. **We recommend implementation as a precursor to forest plan revision as part of analyzing the existing management situation in preparation for the need for change.**

Monitoring frequency varies for each indicator and measure for purely methodological reasons depending on the measurement method, the sensitivity of the measure to change, and desired accuracy and precision. But the frequency of monitoring for specific indicators and measures may also be adjusted to ensure that priority indicators are tracked more frequently. Although annual reporting of monitoring data will be required for a number of purposes, a more complete sustainability assessment may be conducted in preparation for forest plan revision and periodically between times. Others involved in producing "state of system" type efforts typically have full assessment and reporting frequencies within 3- to 5-year time interval. LUCID forest teams **recommended that an assessment frequency of approximately 5 years would be operationally realistic and allow for meaningful detection of change**.

Phased Implementation

To properly support forests and to ensure the needed enhancements and improvements to the process and tools, **we recommend a phased implementation process that starts with a subset of national forests ready to engage the process.** Forests preparing for revision are suggested as likely candidates, but forests wishing to use the process of sustainability monitoring to build collaborative relationships or to coordinate with other land managers (e.g., national forests within an ecoregion) may also wish to coordinate their monitoring efforts and build relationships and monitoring efficiencies.

A phased implementation process would also provide an opportunity to continue to develop and enhance the process and tools recommended in this report and allow costs and other feasibility issues to be tracked in a typical situation.

Next Steps

The LUCID Project provided an opportunity to test and develop a number of aspects of FMU-scale sustainability monitoring, but it also raised a number of issues and areas needing further work. Highlights of tactical issues for the next steps in implementing FMU-scale sustainability monitoring are described below.

TACTICAL IMPLEMENTATION

KEY RECOMMENDATIONS/HIGHLIGHTS

- ☑ We recommend that the goals of implementation should be not just to ensure a set of nationally consistent and efficient products but also an implementation approach that promotes and facilitates the dialogue and learning within and among national forests staff and the public.
- ☑ We recommend a forest team of approximately five people consisting of specialists from ecological, social, and economic disciplines plus a GIS analyst and a team leader.
- ☑ We recommend establishing a core technical assistance group that can build a community of practice about sustainability monitoring. This team can facilitate the implementation of FMU-scale sustainability monitoring creating efficiencies between forest efforts and improving consistency.
- ☑ We recommend the development and enhancement of tools that can serve as interactive repositories of monitoring components.
- ☑ We recommend that forests should be encouraged to continue the practice of developing collaborative partnerships with outside specialists.
- ☑ We recommend the establishment of a network of research and regional office specialists to support forest-scale sustainability monitoring initiatives.
- ☑ We recommend that FMU-scale sustainability monitoring should be linked to the new Planning Rule business requirements models.
- ☑ We recommend implementation as a precursor to forest plan revision as part of analyzing the existing management situation in preparation for the need for change.
- ☑ We recommend that an assessment frequency of approximately 5 years would be operationally realistic and allow for meaningful detection of change.
- ☑ We recommend a phased implementation process that starts with a subset of national forests ready to engage the process.
- ☑ We recommend that in keeping with a phased implementation approach costs should be tracked carefully for forests implementing FMU-scale sustainability monitoring.

NEXT STEPS FOR FMU-SCALE SUSTAINABILITY MONITORING

Process Support

- ☑ Conduct a business analysis/business model of the sustainability monitoring process.
- ☑ Establish a core of specialists to help facilitate implementation in a consistent manner.
- ☑ Expand and refine the recommended process for sustainability monitoring through business analysis.
- ☑ Provide guidance on ways to ensure access to social and economic expertise during sustainability monitoring.
- ☑ Foster coordination with research to pursue research items.
- ☑ Develop the C&I Resource Database as a web-enabled interactive repository of C&I FMU-scale information. This tool would provide an easy means of coordinating across the national forests system, would aid in collaborative approaches with a broad range of stakeholders, and would improve consistency.
- ☑ Provide interactive (e.g., web-enabled) mechanism to track and document the experiences and lessons learned of those involved in sustainability monitoring.

Systems Framework

☑ Produce a set of descriptive materials and examples on systems thinking and systems framework suitable for multiple audiences (e.g., technical papers, fact sheets, Power Point presentations).

☑ Prepare an example of an existing monitoring program and forest plan document revised within a systems framework.

Scale

☑ Provide examples of the process of identifying the study area including consideration of spatial scale in terms of areas of influence and collaborative initiatives (e.g., across multiple ownerships).

Indicators

☑ Expand indicator component of database to capture samples of questions associated with the indicator (including analytical questions, questions addressing indicator interactions, and questions at a range of spatial scales).

Measures and Data

Enhance C&I database through more detailed specification of data elements in conjunction with other reviews including:

☑ Review and development of opportunities for sharing and accessing data and protocols from corporate data sets (e.g., NRIS, ALP, INFRA, TIM-FACTS) and protocols (e.g., IMIT, FIA, FHM).

☑ Review measures and data requirements with the technical measures team for the 2003 Montreal Process report to identify data elements that can be leveraged by collection at multiple scales.
Work with first set of forests to implement such an approach to identify common data elements.
Review and develop guidance and procedures for quality assurance/quality control for data acquisition.

Reference Values

☑ Produce consistent definitions of types (categories) of reference values including those addressing short-term vs. long-term outcomes.

☑ Resolve (strategic decision) the role of collaborators in establishing reference values and in approving reference values.

☑ Produce standardized definitions of the interpretation of technical aspects of reference values (e.g., to facilitate consistent usage of fuzzy logic reference values).

Analytical Tools

☑ Adapt and modify analytical modeling tools to resolve known problems and to synchronize with government software.

☑ Provide guidance (and standardized definitions and usage) on appropriate use of aggregation algorithms for analysis.

☑ Provide standardized (consistent) definitions for components of analytical tool (e.g., interpretation of terms used in reference values, weighting).

Analysis, Synthesis and Reporting

☑ Determine minimum common requirements for analysis and reporting.

RESEARCH RECOMMENDATIONS

The applied research approach of the LUCID Project provided an opportunity to explore and innovate in a number of areas including the use of a systems approach to understanding and monitoring for sustainability, the identification of critical indicators and development of measures, the role and value of reference values, and techniques and approaches to assessing sustainability. The six LUCID forest teams examined these issues and approaches and experiences and together contributed to the body of knowledge and practice about sustainability monitoring.

Through the LUCID Project, however, new questions and challenges were raised, presenting the need for further research and development.

Based on the experience of the six tests, a series of recommendations for further research were developed. Some of the recommendations are fairly broad in scope, suggesting a general topic area for research. Other recommendations are process-oriented and focus on developing approaches and mechanisms to assist in the transfer of research knowledge to the forest or on facilitated discussions about complex issues. The list concludes with a set of research recommendations that came from the forest teams and are forest-specific in nature. The research recommendations are organized by topic corresponding with the chapter headings. Readers can refer to the associated chapter for additional information and the broader context of the recommendations.

RESEARCH RECOMMENDATIONS

SYSTEMS-BASED APPROACHES TO SUSTAINABILITY MONITORING

- ☑ Further research should pursue the application of systems theory concepts to social and economic systems and assist the identification of fundamental systems properties and interactions.
- ☑ Additional research and discussion should examine at what coarser scales a systems perspective (based on the idea of forests as joint production systems) becomes generalized to the point of obscuring its value.
- ☑ Further research should examine the relationships between indicators organized within systems-based frameworks and those developed within issue- or goal-oriented frameworks.
- ☑ Additional research should be conducted to investigate the relationships between indicators and system properties.
- ☑ The recommended and optional measures to identify the perspective of the observer and to reveal how the perspective of the observer affects the definition of the indicator or its measurement should be investigated Strategies to reveal this orientation and present it in a meaningful way to forest users are required.

SPATIAL AND TEMPORAL SCALE ISSUES

- ☑ Research should reveal how to match the scale at which data are collected with the appropriate scale for the question/indicator. This is particularly true for economic and social indicators where much of the readily available data appears to come from a different scale (e.g., county/census data instead of community-level data). The research response required may be assistance in identifying and reconciling scale issues, and it may also require primary investigations to collect the desired information at the right scale.
- ☑ Research should help construct both historical understanding of forest (ecological, social and economic) conditions as well in identifying possible future visions. This information can be used specifically to help in the construction of reference values.
- ☑ Research should examine the applicability and appropriateness of common measures and common reference values by ecoregion.

MONITORING HIERARCHIES: PRINCIPLES AND CRITERIA

- ☑ Research should investigate the appropriateness of the social framework and suggest improvements in keeping with the systems context. This applies in particular to the identification of critical social system elements needed to identify the most important indicators.
- ☑ Research should determine which stock and flow (structure/function) components should be examined within which kinds of systems (individual to community or regional economy).

INDICATORS

- ☑ Research should identify which indicators best address the value of natural capital.
- ☑ Research must match outcome indicators and measures for organism systems, particularly genetics.
- ☑ Research should establish more useful social measures particularly, outcome-oriented measures for collaborative stewardship and social and cultural values.
- ☑ Research should investigate ways to reconcile temporal disparities in the long-term aspects of social and economic systems.

MEASURES

- ☑ The LUCID C&I Resource Database needs to be improved and refined. Existing best measures must be included in subsequent revisions to the Database.
- ☑ Research should help develop measurement protocols that provide high quality, outcome-oriented information at the right scale (for example, trade balance not just volume of exports) in all areas.
- ☑ Measures adapted to the unique environments of plantations (particularly the genetic aspects) need to be developed.
- ☑ Further research is needed to find meaningful ways to measure distributional equity.
- ☑ To assist development and testing of the adequacy of the indicators and measures, it would be useful to examine the results of this final suite of C&I developed in the LUCID Project with data and reference values from a national forests as a type of sensitivity test.
- ☑ Additional work is needed to develop protocols and specifically to investigate cost-effective ways of collecting data at the right scale with remote-sensing technologies.

REFERENCE VALUES

☑ Approaches to develop reference values for all measures are needed along with readily accessible sources of information to inform reference value development.

☑ Methods of sensitivity testing reference values should be developed.

☑ The extent to which it may be more likely for there to be consistent reference values between common management units or ecological land units and why it makes a difference should be studied.

ANALYSIS PROCESS AND TOOLS

☑ Research should examine the potential for existing causal models within the Forest Service to be networked using modeling software such as Stella (HPS Inc. 2002) and compiled results used as an input to the analysis phase.

☑ There is a recognized need for the study and development of additional analytical tools and system approaches to truly pursue the interactions.

FOREST-SPECIFIC RESEARCH QUESTIONS

☑ Are there reasonable and cost-efficient methods of tracking carbon flux within systems at the FMU scale?

☑ Are there methods to extrapolate a statistically correct selection of ecological land types (ELT's) that represent the forest?

☑ What are the best indices of genetic and biological diversity of the forest?

☑ What are the best data sources for socioeconomic data appropriate to the FMU scale?

☑ How can the existence and abundance of exotic species (and genetically modified taxa) be effectively over the long-term?

☑ What are the best methods for monitoring disturbance extent from fire, storms, and insects, including a methodology for identifying, mapping, and setting reference values?

☑ What species are most subject to genetic effects and what is a methodology for selecting and evaluating these effects?

☑ What are the best ways to identify target species for gene frequency impacts and what is a methodology for selecting taxa, determining appropriate reserve size, and setting reference values?

☑ How can primary data be collected relevant to social system components such as scenery, measuring social encounters, recreation use, use and nonuse values, and community level economic modeling.

☑ What are historical vegetation conditions both in type and structure? Especially, what were the historical conditions, late 1800s, for nonforest systems?

☑ Have past and current climatic changes affected vegetation type and structure arrangement on the landscape?

CONCLUSIONS

This report documents a journey and a set of lessons learned by a group of dedicated national forests employees and partners. Like sustainability itself, we shared a common goal but we all had different understandings of how to make progress, how fast to go, and even sometimes, in what direction. Together, however, we began to develop a common language to discuss our values and our perspectives and together we made significant steps towards the development of a set of tools and a process to help others monitor their progress in a quest for sustainability.

While much of the experience is still fuzzy in our minds, there are some common themes that stand out as key messages and lessons learned:

- It is important to recognize that sustainability is a social concept and one that is incredibly valuable even though its definition and its measurement are elusive.
- Developing a common language for sustainability is the way to help us tell the stories of sustainability that are unique to each forest and to each community.
- Sustainability can't be achieved by any one group of people, at one scale, and certainly not by the Forest Service acting alone. We need to act on multiple fronts, multiple scales, with our partners and get outside our boundaries, both physical and mental.
- In the face of uncertainty and multiple values, sustaining the contexts that sustain us, the fundamental systems, is the way to move forward.
- Systems-based approaches can help provide an organizing framework to understand how system components and functions work together. Systems frameworks provide an organizing tool to develop a monitoring program that turns data into knowledge by helping us select indicators and by providing a guide to analyze that information. But more importantly, a systems approach can be used to enrich our understanding of how the pieces and components of ecological, social, and economic systems work together; and this has application far greater than a specific monitoring program.
- Sustainability is inherently a long-term concept, and monitoring is a process to take repeated measures over time. Sustainability assessment is not a one-shot deal. To be effective, we need to ensure that sustainability monitoring continues in the long-run and we need to track the direction and rate of change of our progress over time.
- Sustainability assessments are relative not deterministic in nature and should involve people in a discussion about sustainability.
- Sustainability monitoring is an iterative process. The development of indicators and an approach to monitoring was built on the experience of others and others, after us will propose many good revisions and changes. Future iterations are required and necessary, but we should not be paralyzed into a state of inaction because we know we haven't got everything right yet. Start now. Refine as we learn.
- Tools and models and computer programs will never be as powerful at integrating as the human mind, particularly when we collaborate with our partners. Use tools and models to help us but remember the value in discussing together how and why things are working the way they are.
- All results are contextual and without sufficient detail and interpretation have little meaning. Techniques that explain the context, the interrelationships and the uncertainties are the most useful in building understanding.
- The complementary action to managing and monitoring for sustainability is living sustainability. Personal responsibility for sustainability rests with each employee, each resident, and each forest visitor.
- The establishment and implementation of a sustainability-monitoring program at the forest management unit scale represents one approach to sustaining the systems, the contexts, that sustain us and as a result represents the way to sustain our diverse perspectives on the things that we individually value about healthy lands, healthy communities, and healthy economies.

BIBLIOGRAPHY

Allen, T. F. H., and T. W. Hoekstra. 1990. "The confusion between scale–defined levels and conventional levels of organization in ecology." *Journal of Vegetation* Science 1:5–12.

Allen, T. F. H., and T. W. Hoekstra. 1992. *Toward a unified ecology.* New York: Columbia University Press.

Allen, T. F. H., and Hoekstra, T. W. 1994. Toward a definition of sustainability. In *Sustainable ecological systems: Implementing an ecological approach to land management.* W. W. Covington and L. F. DeBano, tech. coord. Fort Collins, CO: USDA Forest Service: Rocky Mountain Range and Forest Experiment Station General Technical Report 247. pp. 363.

Allen, T. F .H., R. V. O'Neill, and T. W. Hoekstra. 1985. *Interlevel relations in ecological research and management: Some working principles from hierarchy theory*. Fort Collins, CO: USDA Forest Service, Rocky Mountain Range and Forest Experiment Station, General Technical Report RM–110. 11 p.

Allen, T. F. H., J. A. Tainter, and T. W. Hoekstra. No Date. *Supply–side sustainability.* New York: Columbia University Press, (in press).

Aplet, G. H., N. Johnson, J. T. Olson, and V. A. Sample, eds. 1993. *Defining sustainable Forestry*. Washington, DC: Island Press.

Appanah, S., and M. Kleine. 2000. *Auditing of sustainable forest management: A practical guide for developing local auditing systems based on ITTO's criteria and indicators.* Working Paper 4. Forest Certification Project of the Deutsche Gesselschaft fur Technische Zusammenarbeit.

Bailey, R. G. 1995. *Description of the ecoregions of the United States*. 2d ed. USDA Forest Service Misc. Pub. No. 1391, Map scale 1:7,500,000. 108 p.

Bartelmus, P. 1997. "Measuring Sustainability: Data Linkage and Integration." In *Sustainability Indicators: Report of the project on indicators of sustainable development.* Edited by B. Moldan and S. Billharz. New York: John Wiley and Sons.

Beckley, T. M., and T. M. Burkosky. 1999. Appendix 1: A matrix of indicator approaches to community sustainability. In *Social indicator approaches to assessing and monitoring forest community sustainability.* Edmonton, Alberta: Natural Resources Canada, Canadian Forestry Service, Northern Forestry Centre Inf. Rep. NOR–X–360.

Blakeney, J., R. Z. Donovan, S. Higman, and R. Nussbaum. 1998. *Certifier evaluation and field test of the CIFOR C&I (Draft Report)*. Criteria and Indicators for Sustainable Forest Management. CD–ROM. Center for International Forestry Research.

Bosworth, D. 2001. *The Forest Service Role in Fostering Sustainability*. Speech By USDA Forest Service Chief. Washington, DC: Society of American Foresters meeting. May 29, 2001. Text available online at http://www.fs.fed.us/intro/speech/2001/2001may29–Bosworth.html.

British Columbia Round Table on the Environment and the Economy. 1993. *Strategic directions for community sustainability*. Victoria: British Columbia Round Table on the Environment and the Economy.

Brown, T. C., and G. L. Peterson. 1994. A Political–Economic Perspective on Sustained Ecosystem Management. In *Sustainable ecological systems: Implementing an ecological approach to land management.* W. W. Covington and L. F. DeBano, tech. coord. Fort Collins, CO: USDA Forest Service: Rocky Mountain Range and Forest Experiment Station General Technical Report 247. 363 p.

Canadian Model Forest Program. 2000. *A user's guide to local level indicators of sustainable forest management: Experiences from the Canadian model forest network.* Natural Resources Canada.

Canadian Model Forest Network. 2002. *Local level indicators of sustainable forest management.* http://www.modelforest.net/e/home_/locallee.html.

Castaneda, F. C. 2000. Why National and Forest Management Unit Level Criteria and Indicators for Sustainable Management of Dry Forests in Asia? In *Development of National–level Criteria and Indicators for the Sustainable Management of Dry Forests in Asia.* Background papers. Edited by T.L. Cheng and P.B. Durst. Food and Agricultural Organization of the United Nations.

Castaneda, F., C. Palmberg–Lerche, and P. Vuorinen. 2001. *Criteria and indicators for sustainable forest management: A compendium.* Rome, Italy: Food and Agriculture Organization, Forest Resources Development Service, Forest Resource Division. Forest Management Working Paper No. 5.

Canadian Council of Forest Ministers (CCFM). 2000. *Criteria and Indicators of Sustainable Forest Management in Canada.* National Status 2000. Canadian Council of Forest Ministers.

Cheng, T. L., and P. B. Durst. 2000. *Development of national–level C&I for the sustainable management of dry forests in Asia.* Background Papers. Food and Agricultural Organization of the United Nations.

Center for International Forestry Research. (CIFOR). No Date. *Criteria and indicators for sustainable forest management.* Criteria and Indicators CD–ROM available from Jalan CIFOR, Situ Gede, Sindangbarang, Bogor Barat 16680 Indonesia.

Center for Internaitonal Forestry Research (CIFOR). 1996. *Testing criteria and indicators for sustainability management of forests: phase 1 final report.* CIFOR Special Publication, Bogor, Indonesia.

Clark Labs. 2002. *idrisi.* Worcester, MA: Clark University. Available online at: http://www.clarklabs.org/Contact.asp

Clayoquot Sound Scientific Panel. 1995. *Sustainable ecosystem management in Clayoquot Sound.* Victoria, BC, Canada: Cortex Consultants Inc. Report 5.

Clawson, M. 1975. *Forests for whom and for what?* Washington, DC: John Hopkins University Press.

Colfer, C. J. P., Y. Byron, R. Prabhu, and E. Wollenberg. 2001. "History and conceptual framework." In *People managing forests: The link between human well–being and sustainability.* Edited by Colfer, C. J. P. and Y. Byron. Washington, DC: Resources for the Future.

Colfer, C., R. Prabhu, M. Gunter, C. McDougall, N. Miyasaka Porro, and R. Porro. 1999. *Who counts most? Assessing human well–being in sustainable forest management.* Criteria and Indicators Toolbox Series No. 9. Bogor, Indonesia: Center for International Forestry Research.

Colfer, C., R. Prabhu, and E. Wollenberg. 1995. *Principles, Criteria and Indicators: Applying Ockam's Razor to the People—Forest Link.* Working Paper No. 8. Bogor, Indonesia: Center for International Forestry Research.

Convention of Biological Diversity. 1992. *Secretariate of the convention on biological diversity.* United Nations environment program. Available online at http://www.biodiv.org/doc/legal/cbd–en.pdf.

Coufal, J.E. 1999. Sustain, sustainable, sustained. *New York Forest Owner. 37(3):9.*

Dixon, J.A., and L.A. Fallon. 1989. "The concept of sustainability: Origins, extensions, and usefulness for policy." *Society and Natural Resources* 2:73–84.

Doak, S.C., and J. Kusel. 1997. *Well–being assessment of communities in the Klamath Region: Forest community research.* Prepared for USDA Forest Service, Klamath National Forest # 43–91W8–6–7077. Taylorsville, California (self-published).

Environment Canada. 2002. *Sustainable communities indicator program.* Available online at http://www.ec.gc.ca/scip–pidd/English/scip_intro.cfm.

FAO (Food and Agriculture Organization). 2001a. *Global forest resources assessment 2000.* Rome, Italy: Food and Agriculture Organization of the United Nations Forestry Paper 140.

FAO (Food and Agriculture Organization). 2001b. *State of the World's Forests 2001.* Rome, Italy: Food and Agriculture Organization of the United Nations.

Farrell, A., and M. Hart. 1998. "What does sustainability really mean? The search for useful indicators." *Environment* (40)9:4–9.

Flood, R. L., and E. R. Carson. 1993. *Dealing with complexity*. New York: Plenum Press.

Floyd, D. W., S. L. Vonhof, H. E. Seyfang, J. Heissenbuttel, R. Cantrell, L. Stocker, B. Wilkinson, and K. Connaughton. 2001. "Forest sustainability: A discussion guide for professional resource managers." *Journal of Forestry* 99(2) 8–31.

Forbes, G., H. Veen, J. Loo, V. Zelazny, and S. Woodley. 1998. "Ecological change in the greater Fundy Ecosystem." In *State of the greater Fundy Ecosystem*. Edited by S. Woodley, G. Forbes and A. Skibicki. Fredericton: University of New Brunswick. Greater Fundy Ecosystem Research Group.

Forem Technologies, Ltd. 2001. *ALCES: An integrated landscape management tool.* Bragg Creek, AB. Canada: Forem Technologies Ltd. Also available online at http://www.foremtech.com/products/pr_alces.htm.

Gallopin, G. C. 1997. "Indicators and their use: Information for decision–making." In *Sustainability Indicators: Report of the project on indicators of sustainable development.* Edited by B. Moldan and S. Billharz. New York: John Wiley and Sons.

Geissler, P. No Date. *Conceptual Models*. URL last accessed on December 9, 2001. Available at: www.mp1–pwrc.usgs.gov/fgim/cmodel.html

Gillespie, A. J. R. 2001. Personal conversation on FIA data applicability to LUCID. Forest Inventory National Program Leader, USDA FS, Research and Development, P.O. Box 96090, Washington, DC 20090-6090.

Goodenough , D. A., S. Bhogal, R. Fournier, R. J. Hall, J. Iisaka, D. Leckie, J. E. Luther, S. Magnussen, O. Niemann, and W. M. Strome. 1998. *Earth observation for sustainable developments of forests*. Project Description. Victoria, British Columbia: Natural Resources Canada.

Government of Canada. 1998. *Sustainable community indicators program*. Version 1.1. Canadian Housing and Mortgage Corporation and Environment Canada.

Gregersen, H., A. Lundren, and N. Byron. 1998. "Forestry for sustainable development: Making it happen." *Journal of Forestry* 96(3):6–11.

Grimm, N. B., J. Grove, and C. L. Redman. 2000. "Integrated approaches to long–term studies of urban ecological systems." *BioScience* (50)7:571–585.

Grumbine, R. E. 1994. "What is ecosystem management?" *Conservation Biology* 8(1) 27–38.

Grumbine, R. E. 1997. Reflections on "What is ecosystem management?" *Conservation Biology* 11(1):41–47.

Hardoy, J. E., D. Mitlin, and D. Satterthwaite. 1992. *Environmental problems in third world cities.* London: Earthscan Publications.

Harris, C. C., W. J. McLaughlin, and G. Brown. 1998. "Rural communities in the Interior Columbia Basin: How resilient are they?" *Journal of Forestry* (96)3:11–16.

Hart, M. 1999. *Guide to sustainable community indicators.* 2nd Edition. Hart Environmental Data, P.O. Box 361, N. Andover, MA 01845. p. 202.

Hartl, D. L. 1988. *Primer of population genetics*. 2nd Edition. Sunderland, MA: Sinauer Associates.

Harwell, M. A. 1999. "A framework for an ecosystem integrity report card." *BioScience* (49)7:543–557.

Helms, J. A. 1998. *The dictionary of forestry.* Bethesda, MD: Society of American Foresters.

Henderson, H. 1991. *Paradigms of progress: Life beyond economics*. Indianapolis, IN: Knowledge Systems, Inc.

High Performance Systems (HPS), Inc. 2001. "A pressing need: Improving performance." In *Introduction to systems thinking*. ithink© 1992–1997, 2000. Available online at http://www.hps–inc.com/download/pdfs/iISTguidechapter1.pdf.

High Performance Systems (HPS), Inc. 2002. *Stella.* Version 7.0. Hanover, NH: High Performance Systems, Inc.

Hobbs, R. J. 1998. "Managing ecological systems and processes." In *Ecological scale, theory and applications*. Edited by D. L. Peterson and V. T. Parker. New York: Columbia University Press.

Hoekstra, T. W., T. F. H. Allen, J. Kay, and J. A. Tainter. 1998. "Criteria and indicators for ecological and social system sustainability with system management objectives." *In CIFOR North American test of criteria and indicators of sustainable forestry.* Vol. 1. Compiled by S. Woodley, G. Alward, L. Iglesias Gutierrez, T. Hoekstra, B. Holt, L. Livingston, J. Loo, A. Skibicki, C. Williams, and P. Wright. Fort Collins, CO: USDA Forest Service, Inventory and Monitoring Institute Report No. 3. Available online at http://www.fs.fed.us/institute/cifor/cifor_1.html.

Hoekstra, T. W., T. F. H. Allen, J. A. Tainter, and J. Kay. No Date. *Living systems: A framework for inventory, monitoring and planning.* USDA Forest Service Ecosystem Sustainability Corporate Team and the Inventory and Monitoring Issues Team. Available from the USFS Inventory and Monitoring Institute. In preparation.

Holling, C. S. 1986. "Resilience of ecosystem: Local surprise and global change." In *Sustainable development of the biosphere*. Edited by W. C. Clark and R. E. Munn. Cambridge: Cambridge University Press.

Holling, C. S., F. Berkes, and C. Folke. 1998. "Science, sustainability and resource management." In *Linking social and ecological systems: Management practices and social mechanisms for building resilience*. Edited by F. Berkes and C. Folke. Cambridge: Cambridge University Press.

Holt, B. 2001. Industrial perspectives on criteria and indicator monitoring for sustainability at the forest management unit scale. Crystal City, VA: Environmental Performance Indicators.

Hunt, B. B. 1987. "Public opinion and public forestry." Journal of Forestry 85: 13–14.

International Institute for Sustainable Development. 2002. Measurement and indicators for sustainable development: dashboard model. Available on line at: www.iisd.org/cgsdi/intro_dashboard.htm.

Jacobs, M. 1991. *The Green Economy*. London: Pluto Press.

Kates, R. W., W. C. Clark, R. Corell, J. M. Hall, C. C. Jaeger, I. Lowe, J. J. McCarthy, H. J. Schellnhuber, B. Bolin, N. M. Dickson, S. Faucheux, G. C. Gallopin, A. Gruebler, B. Huntley, J. Jäger, N. S. Jodha, R. E. Kasperson, A. Mabogunje, P. Matson, H. Mooney, B. Moore, III, T. O'Riordan, and U. Svedin. 2001. *Sustainability Science*. Cambridge, MA: Environment and Natural Resources Program, Belfer Center for Science and International Affairs, Kennedy School of Government, Harvard University. Research and Assessment Systems for Sustainability Program Discussion Paper 2000–33. Available online at http://sust.harvard.edu.

Kay, J. J., and J. Foster. 1999. About teaching systems thinking. In *Proceedings of the HHK conference*. Edited by G. Savage and P. Roe. Ontario: University of Waterloo. June 14–16, 1999. pp. 165–172. Available online at http://www.fes.uwaterloo.ca/u/jjkay/pubs/systems/.

Kidney, W. C., ed. 1985. *Webster's new compact dictionary*. Nashville, TN: Thomas Nelson, Inc.

King, A. W. 1993. "Considerations of scale and hierarchy." In *Ecological integrity and the management of ecosystems*. Edited by S. J. Woodley and J. Kay and G. Francis. Delray Beach: FL: St. Lucie Press. pp. viii, 220.

Kosko, B. 1993. *Fuzzy thinking*. New York. Hyperion/Disney Books. 318 p.

Kusel, J. 1996. "Well–being in forest–dependent communities." In *Assessments and scientific basis for management options*. Vol. II. Davis, CA: Univ. California. Final report to Congress. pp. 361–373.

Lammerts van Bueren, E. M. L., and E. M. Blom. 1997. *Hierarchical framework for the formulation of sustainable forest management standards*. Leiden, The Netherlands: Tropenbos Foundation.

Lande, R., and G. F. Barrowclough. 1987. "Effective population size, genetic variation, and their use in population management." In *Viable populations for conservation*. Edited by M. Soule. New York: Cambridge University Press.

Landres, P. B. 1995. “The role of ecological inventorying and monitoring in managing wilderness.” *Trends* (32)1:10–13.

Lautenschlager, R.A. 1998. From rhetoric to reality: using specific environmental concerns to identify criticla sustainability issues. *Ecosystems*. No. 1: 176-182.

Ledig, F. T. 1992. “Human impacts on genetic diversity in forest ecosystems.” *OIKOS* 63:87–108.

Lee, K. N. 1993. Compass and gyroscope: Integrating science and politics for the environment. Washington, DC: Island Press.

Li, Bai–Lian. 2001. “Fuzzy statistical and modeling approach to ecological assessments.” In *A guidebook for integrated ecological assessments*. Edited by M. E. Jensen and P. S. Bourgeron. New York: Springer–Verlag, Inc.

Loucks, D. P. 1997. “Quantifying trends in system sustainability.” *Hydrological Sciences Journal* (42)4:513–530.

Loucks, L. 1999. *Building a shared vision for the Ucluelet and area community.* Symposium Report. Written for the Ucluelet and Area Community Vision Society. Long Beach Model Forest. Ucluelet, British Columbia, Long Beach Model Forest. 26 p.

Machlis, G. E., J. E. Force, and S. E. Dalton. 1994. *Monitoring social indicators for ecosystem management*. Prepared for the Interior Columbia Basin Ecosystem Management Project. Available online at http://www.icbemp.gov/science/scirpte.html.

Maclaren, V. W., S. Labatt, J. McKay, and M. Vande Vegte. 1996. *Developing indicators of urban sustainability: A focus on the Canadian experience*. Prepared for Environment Canada, Canada Mortgage and Housing Corporation; Intergovernmental Committee on Urban and Regional Research for Measuring Urban Sustainability: Canadian Indicators Workshop, June 19–21, 1995. ICURR Press: Toronto.

Maine Forest Service. 1999. *The state of the forest and recommendations for forest sustainability standards*. Final report to the Joint Standing Committee of the 119th Legislature on Agriculture, Conservation and Forestry. Augusta, ME.

Manley, P. N., W. J. Zielinski, and C. O. Napper. 2000. “Monitoring ecosystems in the Sierra Nevada: The conceptual model foundation.” *Environmental Monitoring and Assessment* 64:139–152.

McCool, S. F., and R. Haynes. 1995. *Sustainability*. Prepared for the Interior Columbia Basin Ecosystem Management Project. Available online at http://www.icbemp.gov/science/scirpte.html or http://www.icbemp.gov/science/mccool.pdf.

McPherson, P K. 1993. “A perspective on systems science and systems philosophy.” In *Dealing with Complexity*. Edited by R. L. Flood and E. R. Carson. 1993. New York: Plenum Press.

Mendoza, G. A., R. Prabhu, and H. Purnomo. (No Date). *Integrating multiple criteria decision making and geographic information systems for assessing sustainability of tropical forests.* Criteria and indicators for sustainable forest management CD–Rom. Center for International Forestry Research.

Meridian Institute. 2001. Comparative analysis of the Forest Stewardship Council and Sustainable Forestry Initiative Certification Programs: Consensus statement on salient similarities and differences Between the two programs. Prepared for the Forest Stewardship Council–US. Bethesda, MA: The Home Depot and the Sustainable Forestry Initiative of the American Forest and Paper Association.

Merriam–Webster. 1998. Merriam–Webster’s Collegiate Dictionary. Springfield, MA: Merriam–Webster, Inc.

Miles, P. D. 2002. “Using biological criteria and indicators to address forest inventory data at the State level.” Forest Ecology and Management 155:171–185.

Ministerial Conferences on the Protection of Forests in Europe. 1993. Second Ministerial Conference in Helsinki. Resolution H1 General Guidelines for the Sustainable Management of Forests in Europe. Available online at: http://www.mmm.fi/english/forestryh/policy/minkonf/second_main.htm.

Montreal Process Technical Advisory Committee. 1999. Possible application of Montreal Process national criteria and indicators at the sub–national level. Draft paper submitted to the Montreal Process working group in Charleston, SC. November 29, 1999.

Moote, A., A. Conley, K. Firehock, and F. Dukes. 2000. Assessing research needs: Summary of a workshop on community–based collaboratives. Udall Center Publications 00–5.

Morelan, L. 2002. Personal communication. Forester. 1249 S. Vinnell Way, Suite 200, Boise, ID 83709. Boise National Forest.

Mulder, B. S., B. R. Noon, T. A. Spies, M. G. Raphael, C. J. Palmer, A. R. Olsen, R. H. Reeves, and H. H. Welsh. 1999. *The strategy and design of the effectiveness monitoring program for the northwest forest plan*. USDA Forest Service Pacific Northwest Research Station PNW–GTR–437.

Namkoong, G., T. Boyle, Y. El–Kassaby, G. Eriksson, H. R. Gregorius, H. Joly, A. Kremer, O. Savolainen, R. Wickneswari, A. Young, M. Zeh–Nlo, and R. Prabhu. [In preparation] *Criteria and indicators for assessing the sustainability of forest management: Conservation of genetic diversity.* Unpublished manuscript. CIFOR, Bogor.

National Association of State Foresters. 1999. *The Use of Criteria and Indicators in Sustainable Forest Management.* National Association of State Foresters Policy Statement. Available online at: www.stateforesters.org/positions/C&I.html.

National Forest System Land and Resource Management Planning, 36 CFR Parts 217 and 219., Final Rule, Federal Register, Volume 65, No. 218, November 9, 2000.

Natural Research Council. 2000. Ecological Indicators for the Nation. Washington, DC: National Academy Press.

Natural Resources Canada. 2000. Local level indicators of sustainable forest management: Publications and reports. CD–ROM. Ottawa, Ontario. Canadian Model Forest Network.

Northeastern Forest Resource Planners Association. 2001. Sourcebook on criteria and indicators of forest sustainability in the northeastern area. Discussion Draft. Available online at: www.na.fs.fed.us/sustainability.

Oregon Progress Board. 2001. Achieving the Oregon shines vision: The 2001 benchmark performance report. Report to the Oregon Legislative Assembly. Available online at www.econ.state.or.us/opb.

Palmer, C. J., and B. S. Mulder. 1997. Chapter 4. Ecosystem Monitoring. Northwest Forest Plan, OPB 775 Summer Street, N.E., Suite 330, Salem, Oregon 97301-1283. Available online at: www.fs.fed.us/pnw/

Paqueo, L. 2000. Forest supervisors pilot LUCID. USDA Forest Service International Programs. Newsletter No. 5. Also available electronically at: (http://www.fs.fed.us/global/news/)

Pearce, D. W., and G. D. Atkinson. 1993. "Capital theory and the measurement of sustainable development: An indicator of "weak" sustainability." *Ecological Economics* (8)2:103–108.

Peterson, D. J., S. Resetar, J. Brower, and R. Diver. 1999. *Forest monitoring and remote sensing: A survey of accomplishments and opportunities for the future*. Prepared for the White House Office of Science and Technology Policy. MR–1111.0–OSTP.

Pielou, E.C. 1991. *After the Ice Age: The return of life to glaciated North America*. Chicago, IL: University of Chicago Press.

Prabhu, R., C. J. P. Colfer, and R. G. Dudley. 1999. *Guidelines for Developing, Testing and Selecting Criteria and Indicators for Sustainable Forest Management*. The Criteria and Indicators Toolbox. Bogor, Indonesia: Center for International Forestry Research.

Precott–Allen, R. 1997. "Barometer of Sustainability." In *Sustainability Indicators: Report of the project on indicators of sustainable development*. Edited by B. Moldan and S. Billharz. New York: John Wiley and Sons.

Random House, Inc. 1980. *The Random House college dictionary*. Revised edition. New York, NY: Random House, Inc.

Redefining Progress, Tyler Norris Associates and Sustainable Seattle. No Date. *The community indicators handbook: Measuring progress toward healthy and sustainable communities.* San Francisco, CA: Redefining Progress.

Rees, W. 1992. “Ecological footprints and appropriated carrying capacity: What urban economics leaves out.” *Environment and Urbanization* (4)2:121 –130.

Reynolds, K., C. Cunningham, L. Bednar, M. Saunders, M. Foster, R. Olson, D. Schmoldt, D. Latham, B. Miller, and J. Steffenson. 1996. “A knowledge–based information management system for watershed analysis in the Pacific Northwest U.S.” *AI Applications* 10:9–22.

Reynolds, K. M. 2001. “Using a logic framework to assess forest ecosystem sustainability.” *Journal of Forestry* 99:26–30.

Richardson, N. H. 1994. *Making our Communities Sustainable: The Central Issue is Will.* Ontario Round Table on Environment and Economy, Toronto.

Robinson, J., G. Francis, R. Legge, and S. Lerner. 1990. “Defining a sustainable society: Values, principles, and definitions.” *Alternatives* (17)36–46.

Romm, J. 1994. “Sustainable forests and sustainable forestry.” Journal of Forestry (92)7:35.

Ruitenbeek, H. J., and C. Cartier. 1998. *Rational exploitations: Economic criteria and indicators for sustainable management of tropical forests.* Center for International Forestry Research working paper.

Rules of Thumb, Inc. 2000. *NetWeaver*. North East, PA: Rules of Thumb, Inc. Software available online at http://www.bjsoftware.com/.

Rules of Thumb, Inc. 2002. *GeoNetWeaver*. North East, PA: Rules of Thumb, Inc. Software available online at http://www.bjsoftware.com/.

Rutherford, I. 1997. “Use of models to link indicators of sustainable development.” In *Sustainability indicators: Report of the project on indicators of sustainable development.* Edited by B. Moldan and S. Billharz. New York: John Wiley and Sons.

Sedjo, R. A., A. Goetzl, and S. O. Moffat. 1999. *Sustainability of temperate forests*. Washington, DC: Resources for the Future.

Shearman, R. 1990. “The meaning and ethics of sustainability.” *Environmental Management* (14)1:1–8.

Singleton, S. 2000. “Co–operation or capture? The paradox of co–management and community participation in natural resource management and environmental policy–making.” *Environmental Politics* 9:1–21.

Slocombe, D. S. 2001. “Integration of Physical, Biological and Socioeconomic Information.” In *A Guidebook for Integrated Ecological Assessments*. Edited by M. E. Jensen and P. S. Bourgeron. New York: Springer–Verlag, Inc.

Society of American Foresters (SAF). 1999. *Task Force on Forest Management Certification Programs.* Task Force. Co–chairs M. Coulombe and M. Brown. Available online at http://www.safnet.org/policy/fmcp1999.doc.

Sterman, J. D. 2000. *Business dynamics: Systems thinking and modeling for a complex world.* McGraw Hill Companies, Inc.

Tainter, J. A. 2001. “Sustainable rural communities. General principles and North American indicators.” In *People managing forests: The links between human well–being and sustainability.* Edited by C. J. P. Colfer and Y. Byron. Washington, D.C: Resources for the Future Press.

Theisen, P. A. 1980. “Maintenance of genetic diversity and gene pool conservation of commercial or potentially commercial tree species in the Pacific Northwest Region United States Forest Service.” In *Proceedings of Servicewide Workshop on Gene Resource Management*. Sacramento, CA: April 14–18, 1980.

Toman, M. A., R. Lile, and D. King. 1998. *Assessing sustainability: Some conceptual and empirical challenges.* Discussion Paper 98–42. Washington, DC: Resources for the Future.

United Nations. 1993. *Integrated Environmental and Economic Accounting*. United Nations reference no. E.93.XVII.12.

United Nations Conference on Environment and Development (UNCED). The global partnership for environment and development: a guide to Agenda 21.

USDA Forest Service. 1997. *Report of the United States on the criteria and indicators for the sustainable management of temperate and boreal forests*. USDA First Approximation Report for Sustainable Forest Management. Washington, DC.

USDA Forest Service. 2001. *The Upper Glade Pilot Project: Overview*. Applegate Adaptive Management Area, Rogue River National Forest.

USDA Forest Service. *Stewardship Contracting Pilot Projects: Multiparty Monitoring and Evaluation*. Notice 3410–11. Available online at: www.fs.fed.us/land/fm/stewardship/final_notice.htm.

USDA Forest Service. 1998a. *Ecosystem Management Decision Support*. Version 2.0. Available online at http://www.fsl.orst.edu/emds/.

USDA Forest Service. 1998b. *Collaborative Stewardship Overview.* Report of the Collaborative Stewardship Team. Available online at: www.fs.fed.us/newcentury/collaborative_stewardship.htm

USDA Forest Service. 1998c. *Forest Inventory Strategic Plan*. USDA Forest Service, Forest Inventory Analysis. Available online at: www.fia.fs.fed.us/library/strategy.pdf.

U.S. Environmental Protection Agency. 1994. *Measuring progress of estuary programs: A manual*. EPA Office of Water. 842–B–94–008.

U.S. Government. 2001. *Memorandum of understanding among Federal agencies responsible for data related to the criteria and indicators for sustainable forest management in the United States.* 01–SU–11130144–010

von Mirbach, M. 2000. Draft. *A user's guide to local level Indicators of sustainable forest management: Experiences from the model forest network*. Canadian Model Forest Network. NR–Can. Ottawa: Canadian Forest Service.

von Mirbach, M. 2000. *Carbon budget accounting at the forest management unit level: An overview of issues and methods*. Canada's Model Forest Program. Natural Resources Canada. Ottawa: Canadian Forest Service.

Wallace, M. G., H. J. Cortner, S. Burke, and M. Moote. 1996. *The role of social science in ecosystem management: Addressing issues of institutional change and policy paradox.* Presented at the 6th International Symposium on Society and Natural Resources, Penn. State University. University Park, Pennsylvania.

Washburn, M. P., and N. E. Block. 2001. *Comparing forest management certification systems and the Montreal Process criteria and indicators*. Available online at: http://www.sustainableforests.net/CI_Certification.pdf

Williams, J., P. Duinker, and C. Wedeles. 1998. *Assessing progress in sustainable forest management: Proposed criteria and indicators for the Upper Great Lakes Region*. Report to the Great Lakes Forest Alliance.

Wondolleck, J. M., and S. L. Yaffee. 2000. *Making collaboration work: Lessons from innovation in natural resource management*. Washington, DC: Island Press.

Woodley, S. J., G. Alward, L. I. Gutierrez, T. W. Hoekstra, B. Holt, L. Livingston, J. Loo, A. Skibicki, C. Williams, and P. Wright. 2000. *North American test of criteria and indicators of sustainable forestry (volume 1)*. Fort Collins, CO: USDA Forest Service, Inventory and Monitoring Institute Report No. 3. Available online at http://www.fs.fed.us/institute/cifor/cifor_1.html.

World Commission on Environment and Development. 1987. *Our Common Future*. Oxford University Press.

World Watch Institute. 2001. *State of the World 2001*. Washington, DC: Worldwatch Institute.

Wright, P. A., G. Alward, T. W. Hoekstra, B. Tegler, and M. Turner. 2002. *Monitoring for forest management unit scale sustainability: The local unit criteria and indicators development (LUCID) test (management edition)*. Fort Collins, CO: USDA Forest Service Inventory and Monitoring Report No. 4. Available online at http://www.fs.fed.us/institute/lucid/final_report/.

Yaffee, S.L., ed. 1996. *Ecosystem management in the United States: An assessment of current experience*. Washington, DC: Island Press.

Zentilli, B. 1997. "Criteria and Indicators for Sustainable Management of Forests." In *Sustainability Indicators: A Report on the Project on Indicators of Sustainable Development*. Edited by B. Moldan, S. Billharz, and R. Matravers. New York: John Wiley and Sons.

Zobel, B. J., and J. T. Talbert. 1984. *Applied Forest Tree Improvement*. New York: John Wiley and Sons.

ACRONYMS

AF&PA	American Forest and Paper Association
AMS	Analysis of the Management Situation
ATO	African Timber Organization
C&I	Criteria and Indicators
CCFM	Canadian Council of Forest Ministers
CIFOR	Center for International Forestry Research
CIFOR-NA	Center for International Forestry Research—North American Test
CIMAT	Criteria and Indicator Modification and Adaptation Tool
EMDS	Ecosystem Management Decision Support
EMS	Environmental Management System
EPA	Environmental Protection Agency
FAO	Food and Agriculture Organization
FAR	First Approximation Report
FHM	Forest Health Monitoring
FIA	Forest Inventory and Analysis
FLT	Forest Leadership Team
FMU	Forest Management Unit
FS	Forest Service
FSC	Forest Stewardship Council
FS Team	Forest Supervisor Team
GIS	Geographic Information Systems
GLFA	Great Lakes Forestry Assessment
HRV	Historic Range of Variability
ICBEMP	Interior Columbia Basin Ecosystem Management Project
ICBEMP	Interior Columbia Basin Ecosystem Management Project
ID Team	Interdisciplinary Team
IMI	Inventory and Monitoring Institute
IMPLAN	Impact Analysis for Planning
ISO	International Standards Organization
ITTO	International Tropical Timber Organization
LLI	Local Level Indicators
LUCID	Local Unit Criteria and Indicator Development
MAB	Man and the Biosphere
MP	Montreal Process
MP TAC	Montreal Process Technical Advisory Committee
MUSY	Multiple-Use Sustained-Yield Act
NEPA	National Environmental Protection Act
NFMA	National Forest Management Act
NFS	National Forest System
NRIS	National Resource Information System
PAO	Public Affairs Officer
PCIM	Principles, Criteria, Indicators, Measures
PCIV	Principles, Criteria, Indicators, Verifiers
PILT	Payments-in-Lieu of Taxes
SCS	Scientific Certification Systems
SEM	Sustainable Ecosystem Management
SFI	Sustainable Forestry Initiative
SFM	Sustainable Forest Management
SPAM	Sierra Province Assessments Monitoring
USFS	United States Forest Service
WCED	World Commission on Environment and Development

GLOSSARY

Adaptive Management—Adaptive management is a systematic process for continually improving management policies and practices by learning from the outcomes of operational programs.

Its most effective form–"active" adaptive management–employs management programs that are de to experimentally compare selected policies or practices, by evaluating alternative signed hypotheses about the system being managed.

Benchmarks—A point of reference, or reference condition, from which measurements can be made or a standard against which others may be judged. Benchmarks can be quantitative or qualitative, input or outcome, short term or long-term.

Biodiversity—The variability among living organisms from all sources, including terrestrial, marine, and other aquatic ecosystems, and the ecological complexes of which they are a part: this includes diversity within species, between species, and of ecosystems.

Capital Substitution—The exchange or transfer of one form of capital for another.

Carrying Capacity –The maximum rate of resource consumption and waste discharge that can be sustained indefinitely in a given region without progressively impairing the functional integrity and productive activity of relevant ecosystems.

Community Capacity—The collective ability of residents to respond (the communal response) to external and internal stresses; to create and take advantage of opportunities; and to meet the needs of residents, diversely defined.

Criterion—A component of the structure or function of the ecological, social, or economic systems, which should be in place as a result of adherence to a principle. Criteria form the conceptual architecture of the systems under investigation.

Data Element—The elemental data that support a measure. Some measures are specific enough that the level of data element is not needed.

Diversity—Diversity in the economic, biological and cultural elements of an urban system helps to increase its ability to adapt to change, and so contributes to urban sustainability.

Ecosystem—A dynamic complex of plant, animal, fungal and microbial communities and the associated nonliving environment with which they interact.

Efficiency—Efficiency is a condition in which benefits are maximized relative to costs.

Increased efficiency in the consumption of resources reduces the need to harvest or extract additional resources. From an urban perspective, increased efficiency in the use of land and resources can be accomplished by reducing sprawl and moving towards a more compact urban form. When the space occupied by the built environment of an urban area becomes more compact in form, economic efficiencies in the provision of public transit services increase and reliance on the automobile as a means of transportation can decrease. The debate over how to implement sustainability goals in an urban context centers in large part on the advantages and disadvantages of compact urban form.

Externalities—The effects that the acts of consumers or producers have on each other. The unanticipated side effects of calculated courses of action.

Ecosystems provide many ecological services in the production of goods and services including assimilation of pollutants or the provision of clean water. Typically, ecosystem charges are external to the decision maker or manager; and as they are unpriced, they are not part of the decision. The issue of externalities refers to the practice or the tendency to ignore the entire costs associated with the production of goods and services.

Forest (u.c.)—Refers to a National Forest.

forest (l.c.)—Refers to a forested environment regardless of ownership.

Forest Management Unit (FMU)—An area approximating a national forests in size. In other countries (e.g., Canada) FMU-level initiatives are referred to as Local Level Indicators (LLI).

Framework—A conceptual model which may or may not hierarchical. Within the context of monitoring frameworks provide the conceptual model "from which relevant indicators can be developed and selected" (Maclaren et al 1996). Monitoring frameworks include: issue-based, sector-based, ecosystem component-based, goal-based, causal-based and systems-based.

Human Well Being—An individual's well-being extends to his or her physical, social, and mental conditions.

Indicator—A quantitative or qualitative parameter that can be assessed in relation to a criterion. Note that indicators have no implied direction, measurement method, spatial or temporal scale or reference value.

Individual Well Being—The positive condition or perception of physical, social, and mental health.

An individual's well-being extends to his or her physical, social and mental well-being. Health and education, by developing human potential, contribute to individual well-being, which also requires the satisfaction of basic physical and economic needs.

Intergenerational Equity—Consideration of the costs and benefits accorded to future generations.

The term "sustainable development" was popularized by the World Commission on Environment and Development (1987) as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." A foremost characteristic of this definition is the concept of inter-generational equity, which embraces the notion that the needs of future generations are as important as the needs of the current generation.

Intra-Generational Equity—Consideration of the costs and benefits accorded to current generations.

This form of equity has two important components: social equity and geographical equity. "Social equity" refers to the fair distribution of the benefits and costs of natural resource use and environmental protection, taking account of such basic human needs as food, shelter, employment, public facilities and services. To many, social equity in the context of sustainability also means the improvement of equity in a broader sense, for example, more equitable distribution of income, and the elimination of discrimination. The second essential component of intra-generational equity is "geographical equity". Geographical equity also implies that sustainable communities support global sustainability by minimizing their contribution to global environmental problems, such as global warming and depletion of the ozone layer.

Intragenerational Equity—All individuals of the present generation have an equal right to benefit from the use of resources.

Living off the Interest of Renewable Resources—Sustainability means that the depletion rates for renewable resources, such as timber and fisheries, should not exceed the regenerative capacity of the natural system that produces them.

Long-Term Economic Development—Enduring economic vitality is an essential component of urban sustainability. This condition is also frequently described as economic "prosperity".

LUCID Unit (LU)—A unified polygon used by the Tongass National Forest LUCID pilot test to describe an *a priori* set of common polygons that were derived from ecoregions, physical land features and boroughs.

Measure—The metrics and sources of information used to quantify the indicator. The methodology and source of information for the indicator. The form, scale, timing, and units of data that are gathered are specified.

Minimal Impact on the Environment—This term implies that waste discharges of all types (including emissions to the air, water effluents, contaminants of land and biota, and the disposal of solid waste) should not exceed the assimilative capacity of the natural environment, where assimilative capacity refers to the capacity of physical, biochemical and geochemical processes in the ecosystem to decompose and render inert certain types of waste products. Impacts due to development and management practices should also be minimal, so that habitat and natural ecosystem functions are preserved as much as possible.

Minimal Use of Non-Renewable Resources—Consumption of non-renewable resources is unsustainable because the resources will eventually run out. Therefore, the emphasis must be on minimizing their use, using them as efficiently as possible, through reduction, reuse and recycling, and by seeking renewable resource substitutes.

Monitoring—The periodic and systematic measurement and assessment of change of an indicator.

Nontimber forest products—Includes game animals, fur-bearers, fruits and seeds, , mushrooms, oils, foliage, medicinal plants, peat and fuel wood,. In this context, such products do not include services provided by forests such as water regulation, biodiversity conservation, recreational and spiritual values, or carbon release offsets.

Norm—A norm is the reference value of the indicator and is established for use as a rule or a basis for comparison.

Precautionary Management—In the face of risk and uncertainty, be cautious in managing natural environments.

Principle—A fundamental law or rule serving as a basis for reasoning and action. An explicit element of the sustainability goal.

Range of historic variation—The range of spatial, structural, compositional, and temporal variation of ecosystem elements (plants, soils, animals) within a period specified to represent "baseline" conditions.

Reference Value—The benchmark, standard, or norm against which the data are assessed. Reference values specify the range or threshold expressing the desired future systems condition over a given period.

Relationshed—An area of land that encompasses the human relationships.

Similar to the ecological concept of watershed.

Resiliency—The ability to return to the original form or elasticity.

Standard—Standards are any agreed upon value or measure and are frequently associated with forest plan standards. Standards may be legal or regulatory targets that must not be violated (e.g., human health water quality standards).

Within the LUCID Test the term standard was initially used as the equivalent of reference value.

Subsidiarity in Organization—Decision-making in society should be located at the lowest appropriate level. Decentralization should prevail so that decisions can be made by and for the communities and individuals most affected, with higher level organizations being "subsidiary" to lower ones.

Subsistence—The harvesting or growing of products directly for personal or family livelihood.

Subsistence needs generally include foodstuffs, fuel-wood, clothing and shelter. Subsistence goods can be considered any good that is a substitute for a market good.

Systematic—

1) Characterized by method—methodical;

2) Arranged in or comprising an order.

A systems approach is not just being systematic or purposeful.

Systems—1) A group of interrelated or interdependent constituents forming a complex whole; 2) An assembly of elements related to an organized whole; 3) Self-organizing entities that have emergent properties and thus are more than the physical and chemical constituents of which they are composed.

Systems Approach—An analytical method to understand the integrity of structural and functional interactions of living systems.

Threshold—Thresholds are the maximum or minimum value of an indicator.

Thresholds indicate the region of change in the value of an indicator beyond which precipitous declines in the value of indicator will occur (e.g., an amount of habitat loss from fragmentation beyond which interior-dwelling species will not be able to survive).

Trade Balance—The ratio of imports to exports.

Trends—Reference values based on an assessment of trends look at change in data values over time and potentially at the rate of change

Verifier—The metrics and sources of information used to quantify the indicator. The methodology and source of information for the indicator. The form, scale, timing, and units of data that are gathered are specified.

Within the LUCID Test the term verifier was original used in place of "measure."

APPENDIX 1.

A SUMMARY OF SOME OF THE INTERNATIONAL AND NATIONAL COMMITMENTS TO SUSTAINABILITY

PRESIDENTIAL DECISION DIRECTIVE

On November 5, 1993, following the United Nations Conference on Environment and Development (known as the Earth Summit) held in Rio de Janeiro, Brazil, for world leaders to explore the link between environment and development, the United States became the first country to commit to the national goal of sustainable forest management when Presidential Decision Directive NSC-16 on Environmental Policy on International Desertification, Forest Conservation, and Fresh Water Security was signed. The Directive states "…The United States is committed to a national goal of achieving sustainable management of United States forests by the year 2000. Our national objectives are that: our nation's forests should be healthy and productive; the growth of our timber should exceed harvest; and our forests should be reservoirs of biological diversity and carbon."

SANTIAGO DECLARATION

In 1995 the United States and nine countries having temperate and boreal forests met in Santiago, Chile, and affirmed their commitment to sustainable forest management and the use of criteria and indicators through the Santiago Declaration. The nine other countries are: Australia, Canada, Chile, China, Japan, Mexico, New Zealand, Republic of Korea, and Russian Federation. Now Argentina and Uruguay also participate. The United States joined the Declaration as part of its customary conduct of foreign relations under 22 USC 2656 and its responsibilities for coordination and oversight over science and technology agreements under 22 USC 2656d (as contained in amendments to the Acts of July 27, 1789). The Santiago Declaration endorsed a way to assess national progress towards sustainable forest management using a common set of Criteria and Indicators now known as the Montreal Process Criteria and Indicators for the Conservation and Management of Temperate and Boreal Forests.

2003 NATIONAL REPORT

As part of the Montreal Process, each participating country will report on the state of its nation's forests and progress towards sustainable forest management by 2003. Individual country reports will be used by the Montreal Process Working Group to prepare the First Montreal Process Forest Report in 2003 for policy makers, forest officials, interest groups, and other stakeholders including industry, scientists, a non-government organizations, international organizations, and academia. The Montreal Process Report will build upon previous reports about the criteria and indicators and will describe forest conditions and management.

FEDERAL INTERAGENCY WORKING GROUP ON SUSTAINABLE DEVELOPMENT INDICATORS

In June 1993, President Clinton established the President's Council on Sustainable Development with a mandate to develop recommended steps the United States could take to realize sustainable development. In its initial report of findings to the President in March 1996, it recommended that the Federal government intensify its effort to develop national indicators of progress towards sustainable development in collaboration with non-governmental organizations and the private sector. In response, a Federal Interagency Working Group on Sustainable Development Indicators (SDI) was established.

INTERGOVERNMENTAL PANEL ON FORESTS

The United Nations Commission on Sustainable Development (UNCSD) was established in December 1992 to ensure follow-up to the Earth Summit. In 1995, the UNCSD met on forests and dryland ecosystems and established an Intergovernmental Panel on Forests (IPF) as a means to continue forest policy dialogue. After two years of work, the IPF recommended over one hundred Proposals for Action that have been reformulated in a Practitioner's Guide to facilitate national implementation. The UNCSD and member countries endorsed the Proposals for Action in 1997.

APPENDIX 2. AGENDA 21:
PROGRAMME OF ACTION FOR SUSTAINABLE DEVELOPMENT
RIO DECLARATION ON ENVIRONMENT AND DEVELOPMENT
STATEMENT OF FOREST PRINCIPLES

The final text of agreements negotiated by governments at the United Nations Conference on Environment and Development (UNCED), 3-14 June 1992, Rio de Janeiro, Brazil[1]

Non-Legally Binding Authoritative Statement of Principles for a Global Consensus on the Management, Conservation and Sustainable Development of all Types of Forests

PREAMBLE

(a) The subject of forests is related to the entire range of environmental and development issues and opportunities, including the right to socio-economic development on a sustainable basis.

(b) The guiding objective of these principles is to contribute to the management, conservation and sustainable development of forests and to provide for their multiple and complementary functions and uses.

(c) Forestry issues and opportunities should be examined in a holistic and balanced manner within the overall context of environment and development, taking into consideration the multiple functions and uses of forests, including traditional uses, and the likely economic and social stress when these uses are constrained or restricted, as well as the potential for development that sustainable forest management can offer.

(d) These principles reflect a first global consensus on forests. In committing themselves to the prompt implementation of these principles, countries also decide to keep them under assessment for their adequacy with regard to further international cooperation on forest issues.

(e) These principles should apply to all types of forests, both natural and planted, in all geographical regions and climatic zones, including austral, boreal, subtemperate, temperate, subtropical and tropical.

(f) All types of forests embody complex and unique ecological processes which are the basis for their present and potential capacity to provide resources to satisfy human needs as well as environmental values, and as such their sound management and conservation is of concern to the Governments of the countries to which they belong and are of value to local communities and to the environment as a whole.

(g) Forests are essential to economic development and the maintenance of all forms of life.

(h) Recognizing that the responsibility for forest management, conservation and sustainable development is in many States allocated among Federal/National, State/provincial and local levels of government, each State, in accordance with its constitution and/or national legislation, should pursue these principles at the appropriate level of government.

---

[1] United Nations Conference on Environment and Development. 1992. United Nations Department of Public Information. New York, NY.

PRINCIPLES/ELEMENTS

1. (a) States have, in accordance with the Charter of the United Nations and the principles of international law, the sovereign right to exploit their own resources pursuant to their own environmental policies and have the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or of areas beyond the limits of national jurisdiction.

   (b) The agreed full incremental cost of achieving benefits associated with forest conservation and sustainable development requires increased international cooperation and should be equitably shared by the international community.

2. (a) States have the sovereign and inalienable right to utilize, manage and develop their forests in accordance with their development needs and level of socio-economic development and on the basis of national policies consistent with sustainable development and legislation, including the conversion of such areas for other uses within the overall socio-economic development plan and based on rational land-use policies.

   (b) Forest resources and forest lands should be sustainably managed to meet the social, economic, ecological, cultural, and spiritual needs of present and future generations. These needs are for forest products and services, such as wood and wood products, water, food, fodder, medicine, fuel, shelter, employment, recreation, habitats for wildlife, landscape diversity, carbon sinks and reservoirs, and for other forest products. Appropriate measures should be taken to protect forests against harmful effects of pollution, including air-borne pollution, fires, pests and diseases, in order to maintain their full multiple value.

   (c) The provision of timely, reliable and accurate information on forests and forest ecosystems is essential for public understanding and informed decisionmaking and should be ensured.

   (d) Governments should promote and provide opportunities for the participation of interested parties, including local communities and indigenous people, industries, labour, non-governmental organizations and individuals, forest dwellers and women, in the development, implementation and planning of national forest policies.

3. (a) National policies and strategies should provide a framework for increased efforts, including the development and strengthening of institutions and programmes for the management, conservation and sustainable development of forests and forest lands.

   (b) International institutional arrangements, building on those organizations and mechanisms already in existence, as appropriate, should facilitate international cooperation in the field of forests.

   (c) All aspects of environmental protection and social and economic development as they relate to forests and forest lands should be integrated and comprehensive.

4. The vital role of all types of forests in maintaining the ecological processes and balance at the local, national, regional and global levels through, inter/alia, their role in protecting fragile ecosystems, watersheds and freshwater resources and as rich storehouses of biodiversity and biological resources and sources of genetic material for biotechnology products, as well as photosynthesis, should be recognized.

5. (a) National forest policies should recognize and duly support the identity, culture and the rights of indigenous people, their communities and other communities and forest dwellers. Appropriate conditions should be promoted for these groups to enable them to have an economic stake in forest use, perform economic activities, and achieve and maintain cultural identity and social organization, as well as adequate levels of livelihood and well-being, through, inter alia, those land tenure arrangements which serve as incentives for the sustainable management of forests.

(b) The full participation of women in all aspects of the management, conservation and sustainable development of forests should be actively promoted.

6. (a) All types of forests play an important role in meeting energy requirements through the provision of a renewable source of bio-energy, particularly in developing countries, and the demands for fuelwood for household and industrial needs should be met through sustainable forest management, afforestation and reforestation. To this end, the potential contribution of plantations of both indigenous and introduced species for the provision of both fuel and industrial wood should be recognized.

(b) National policies and programmes should take into account the relationship, where it exists, between the conservation, management and sustainable development of forests and all aspects related to the production, consumption, recycling and/or final disposal of forest products.

(c) Decisions taken on the management, conservation and sustainable development of forest resources should benefit, to the extent practicable, from a comprehensive assessment of economic and non-economic values of forest goods and services and of the environmental costs and benefits. The development and improvement of methodologies for such evaluations should be promoted.

(d) The role of planted forests and permanent agricultural crops as sustainable and environmentally sound sources of renewable energy and industrial raw material should be recognized, enhanced and promoted. Their contribution to the maintenance of ecological processes, to offsetting pressure on primary/old-growth forest and to providing regional employment and development with the adequate involvement of local inhabitants should be recognized and enhanced.

(e) Natural forests also constitute a source of goods and services, and their conservation, sustainable management and use should be promoted.

7. (a) Efforts should be made to promote a supportive international economic climate conducive to sustained and environmentally sound development of forests in all countries, which include, inter/alia, the promotion of sustainable patterns of production and consumption, the eradication of poverty, and the promotion of food security.

(b) Specific financial resources should be provided to developing countries with significant forest areas which establish programmes for the conservation of forests including protected natural forest areas. These resources should be directed notably to economic sectors which would stimulate economic and social substitution activities.

8. (a) Efforts should be undertaken towards the greening of the world. All countries, notably developed countries, should take positive and transparent action towards reforestation, afforestation and forest conservation, as appropriate.

(b) Efforts to maintain and increase forest cover and forest productivity should be undertaken in ecologically, economically and socially sound ways through the rehabilitation, reforestation and re-establishment of trees and forests on unproductive, degraded and deforested lands, as well as through the management of existing forest resources.

(c) The implementation of national policies and programmes aimed at forest management, conservation and sustainable development, particularly in developing countries, should be supported by international financial and technical cooperation, including through the private sector, where appropriate.

(d) Sustainable forest management and use should be carried out in accordance with national development policies and priorities and on the basis of environmentally sound national guidelines. In the formulation of such guidelines, account should be taken, as appropriate and if applicable, of relevant internationally agreed methodologies and criteria.

(e) Forest management should be integrated with management of adjacent areas so as to maintain ecological balance and sustainable productivity.

(f) National policies and/or legislation aimed at management, conservation and sustainable development of forests should include the protection of ecologically viable representative or unique examples of forests, including primary/old-growth forests, cultural, spiritual, historical, religious and other unique and valued forests of national importance.

(g) Access to biological resources, including genetic material, shall be with due regard to the sovereign rights of the countries where the forests are located and to the sharing on mutually agreed terms of technology and profits from biotechnology products that are derived from these resources.

(h) National policies should ensure that environmental impact assessments should be carried out where actions are likely to have significant adverse impacts on important forest resources, and where such actions are subject to a decision of a competent national authority.

9. (a) The efforts of developing countries to strengthen the management, conservation and sustainable development of their forest resources should be supported by the international community, taking into account the importance of redressing external indebtedness, particularly where aggravated by the net transfer of resources to developed countries, as well as the problem of achieving at least the replacement value of forests through improved market access for forest products, especially processed products. In this respect, special attention should also be given to the countries undergoing the process of transition to market economies.

(b) The problems that hinder efforts to attain the conservation and sustainable use of forest resources and that stem from the lack of alternative options available to local communities, in particular the urban poor and poor rural populations who are economically and socially dependent on forests and forest resources, should be addressed by governments and the international community.

(c) National policy formulation with respect to all types of forests should take account of the pressures and demands imposed on forest ecosystems and resources from influencing factors outside the forest sector, and intersectoral means of dealing with these pressures and demands should be sought.

10. New and additional financial resources should be provided to developing countries to enable them to sustainably manage, conserve and develop their forest resources, including through afforestation, reforestation and combating deforestation and forest and land degradation.

11. In order to enable, in particular, developing countries to enhance their endogenous capacity and to better manage, conserve and develop their forest resources, the access to and transfer of environmentally sound technologies and corresponding know-how on favourable terms, including on concessional and preferential terms, as mutually agreed, in accordance with the relevant provisions of Agenda 21, should be promoted, facilitated and financed, as appropriate.

12. (a) Scientific research, forest inventories and assessments carried out by national institutions which take into account, where relevant, biological, physical, social and economic variables, as well as technological development and its application in the field of sustainable forest management, conservation and development, should be strengthened through effective modalities, including international cooperation. In this context, attention should also be given to research and development of sustainably harvested non-wood products.

(b) National and, where appropriate, regional and international institutional capabilities in education, training, science, technology, economics, anthropology and social aspects of forests and forest management are essential to the conservation and sustainable development of forests and should be strengthened.

(c) International exchange of information on the results of forest and forest management research and development should be enhanced and broadened, as appropriate, making full use of education and training institutions, including those in the private sector.

(d) Appropriate indigenous capacity and local knowledge regarding the conservation and sustainable development of forests should, through institutional and financial support and in collaboration with the people in the local communities concerned, be recognized, respected, recorded, developed and, as appropriate, introduced in the implementation of programmes. Benefits arising from the utilization of indigenous knowledge should therefore be equitably shared with such people.

13. (a) Trade in forest products should be based on non-discriminatory and multilaterally agreed rules and procedures consistent with international trade law and practices. In this context, open and free international trade in forest products should be facilitated.

(b) Reduction or removal of tariff barriers and impediments to the provision of better market access and better prices for higher value-added forest products and their local processing should be encouraged to enable producer countries to better conserve and manage their renewable forest resources.

(c) Incorporation of environmental costs and benefits into market forces and mechanisms, in order to achieve forest conservation and sustainable development, should be encouraged both domestically and internationally.

(d) Forest conservation and sustainable development policies should be integrated with economic, trade, and other relevant policies.

(e) Fiscal, trade, industrial, transportation and other policies and practices that may lead to forest degradation should be avoided. Adequate policies, aimed at management, conservation and sustainable development of forests, including, where appropriate, incentives, should be encouraged.

14. Unilateral measures, incompatible with international obligations or agreements, to restrict and/or ban international trade in timber or other forest products should be removed or avoided, in order to attain long-term sustainable forest management.

15. Pollutants, particularly air-borne pollutants, including those responsible for acidic deposition, that are harmful to the health of forest ecosystems at the local, national, regional, and global levels should be controlled.

APPENDIX 3. "SANTIAGO DECLARATION"

STATEMENT ON CRITERIA AND INDICATORS FOR THE CONSERVATION AND SUSTAINABLE MANAGEMENT OF TEMPERATE AND BOREAL FORESTS

The Governments of Australia, Canada, Chile, China, Japan, Mexico, New Zealand, the Republic of Korea, the Russian Federation and the United States of America, which are participating in the Working Group on Criteria and Indicators for the Conservation and Sustainable Management of Temperate and Boreal Forests ("Montreal Process") and whose countries contain a significant portion of the world's temperate and boreal forests:

Recognizing that the sustainable management of all types of forests, including temperate and boreal forests, is an important step to implementing the Statement of Forest Principles and Agenda 21, adopted by the United Nations Conference on Environment and Development (UNCED), held in Rio de Janeiro in June 1992, and is relevant to the United Nations conventions on biological diversity, climate change, and desertification,

Also recognizing the value of having an internationally accepted understanding of what constitutes sustainable management of temperate and boreal forests, and the value of agreed criteria and indicators for sustainable forest management in advancing such an understanding,

Mindful that the application of agreed criteria and indicators will need to take account of the wide differences among States regarding the characteristics of their forests, including planted and other forests, land ownership, population, economic development, scientific and technological capacity, and social and political structure,

Taking note of other international initiatives regarding the development of criteria and indicators for sustainable forest management,

Affirming their commitment to the conservation and sustainable management of their respective forests, and

Having undertaken substantive discussions to develop agreed criteria and indicators for the conservation and sustainable management of temperate and boreal forests,

Endorse the non-legally binding Criteria and Indicators for the Conservation and Sustainable Management of Temperate and Boreal Forests annexed to this Statement as guidelines for use by their respective policymakers;

Encourage other States which have temperate and boreal forests to consider the endorsement and use of these criteria and indicators;

Note the ongoing nature of the discussion on these criteria and indicators and the need to update the annex as new technical and scientific information and data become available and assessment capability increases; and

Request the Government of Chile, on behalf of the above States, to present this Statement, together with its annex, to the FAO Meeting of Ministers Responsible for Forestry, to be held in Rome, March 16-17, 1995, and the third session of the United Nations Commission on Sustainable Development, to be held in New York, April 11-28, 1995.

Santiago, Chile

February 3, 1995

ANNEX
CRITERIA AND INDICATORS FOR THE CONSERVATION AND SUSTAINABLE MANAGEMENT OF TEMPERATE AND BOREAL FORESTS (THE MONTREAL PROCESS)

SECTION 1: INTRODUCTION

Forests are essential to the long-term well-being of local populations, national economies, and the earth's biosphere as a whole. In adopting the statement of Forest Principles and Chapter I I of Agenda 21, the 1992 UN Conference on Environment and Development (UNCED) recognized the importance of sustainably managing all types of forests in order to meet the needs of present and future generations.

The development of criteria and indicators for the conservation and sustainable management of temperate and boreal forests is an important step in implementing the UNCED Forest Principles and Agenda 21, and is relevant to the UN conventions on biodiversiry, climate change, and desertification. It is also an important step to furthering the joint commitment made by tropical timber consumer countries in January 1994 to maintain, or achieve by the year 2000, the sustainable management of their respective forests.

The criteria and indicators listed under Sections 3 and 4 apply broadly to temperate and boreal forests. They are intended to provide a common understanding of what is meant by sustainable forest management. They also provide a common framework for describing, assessing, and evaluating a country's progress toward sustainability at the national level. They are not intended to assess directly sustainability at the forest management unit level. As such, the criteria and indicators should help provide an international reference for policymakers in the formulation of national policies and a basis for international cooperation aimed at supporting sustainable forest management. Internationally agreed criteria and indicators could also help clarify ongoing dialogues related to international trade in products from sustainably managed forests.

The approach to forest management reflected in the criteria and indicators is the management of forests as ecosystems. Taken together, the set of criteria and indicators suggests an implicit definition of the conservation and sustainable management of forest ecosystems at the country level. It is recognized that no single criterion or indicator is alone an indication of sustainability. Rather, individual criteria and indicators should be considered in the context of other criteria and indicators.

It should be emphasized that an informed, aware, and participatory public is indispensable to promoting the sustainable management of forests. In addition to providing a common understanding of what is meant by sustainable forest management in the temperate and boreal region, the criteria and indicators should be useful in improving the quality of information available not only to decision makers but also to the general public. This in turn should better inform the policy debate at national and international levels.

Each country is unique in terms of the quantity, quality, characteristics, and descriptions of its forests. Countries also differ in terms of forest conditions relative to national population, such as the amount of forest per capita, the amount reforested annually per capita, or the annual forest growth per capita. National circumstances further differ with respect to stages of economic development, land ownership patterns, population patterns, forms of social and political organization, and expectations of how forests should contribute or relate to society.

Given the wide differences in natural and social conditions among countries, the specific application and monitoring of the criteria and indicators, as well as the capacity to apply them, will vary from country to country based on national circumstances. It is anticipated that individual countries would develop specific measurement schemes appropriate to national conditions to address how data would be gathered. Qualitative terms such as "significant" or "low," which are used as indicator descriptors in some cases, would also be defined based on national conditions. Despite these differences, efforts should be made to harmonize the approaches of countries to measuring and reporting on indicators.

Changes in the status of forests and related conditions over time, and the direction of the change, are relevant to assessing sustainability. Therefore, indicators should be understood to have a temporal dimension. This means they will need to be assessed as trends (e.g., at points in time) or with an historical perspective to establish trends. The monitoring of changes in indicators will be essential to evaluating whether and how progress is being made toward the sustainability of forest management at the national level.

While it may be desirable to have quantitative indicators that are readily measured or for which measurements already exist, such indicators alone will not be sufficient to indicate the sustainability of forest management. Some important indicators may involve the gathering of new or additional data, a new program of systematic sampling, or even basic research. Furthermore, some indicators of a given criterion may not be quantifiable. In cases where there are no reasonable quantitative measures for indicators, qualitative or descriptive indicators are important. These may require subjective judgments as to what constitutes effective, adequate, or appropriate national conditions, or trends in conditions, with respect to the indicator.

Concepts of forest management evolve over time based on scientific knowledge of how forest ecosystems function and respond to human interventions, as well as in response to changing public demands for forest products and services. The criteria and indicators will need to be reviewed and refined on an ongoing basis to reflect new research, advances in technology, increased capability to measure indicators, and an improved understanding of what constitutes appropriate indicators of sustainable forest management.

SECTION 2: DEFINITIONS

Criterion: A category of conditions or processes by which sustainable forest management may be assessed. A criterion is characterized by a set of related indicators which are monitored periodically to assess change.

Indicator: A measure (measurement) of an aspect of the criterion; a quantitative or qualitative variable which can be measured or described and which, when observed periodically, demonstrates trends.

Monitoring: The periodic and systematic measurement and assessment of change of an indicator.

Forest type: A category of forest defined by its vegetation, particularly composition, and/or locality factors, as categorized by each country in a system suitable to its situation.

Ecosystem: A dynamic complex of plant, animal, fungal, and microorganism communities and the associated nonliving environment with which they interact.

SECTION 3: CRITERIA AND INDICATORS FOR THE CONSERVATION AND SUSTAINABLE MANAGEMENT OF TEMPERATE AND BOREAL FORESTS-CRITERIA 1-6

The following six criteria and associated indicators characterize the conservation and sustainable management of temperate and boreal forests. They relate specifically to forest conditions, attributes, or functions, and to the values or benefits associated with the environmental and socioeconomic goods and services that forests provide. The intent or meaning of each criterion is made clear by its respective indicators. No priority or order is implied in the alpha numeric listing of the criteria and indicators.

Criterion 1: Conservation of biological diversity.

Biological diversity includes the elements of the diversity of ecosystems, the diversity between species, and genetic diversity in species.

Indicators:

Ecosystem diversity

a. Extent of area by forest type relative to total forest area (a)
b. Extent of area by forest type and by age class or successional stage (b)

c. Extent of area by forest type in protected area categories as defined by IUCN or other classification systems (a)
d. Extent of areas by forest type in protected areas defined by age class or successional stage (b)
e. Fragmentation of forest types (b)

Species diversity

a. The number of forest-dependent species (b)
b. The status (rare, threatened, endangered, or extinct) of forest-dependent species at risk of not maintaining viable breeding populations, as determined by legislation or scientific assessment (a)

Genetic diversity

a. Number of forest-dependent species that occupy a small portion of their former range (b)
b. Population levels of representative species from diverse habitats monitored across their range (b)

Criterion 2: Maintenance of productive capacity of forest ecosystems.

Indicators:

a. Area of forest land and net area of forest land available for timber production (a)
b. Total growing stock of both merchantable and nonmerchantable tree species on forest land available for timber production (a)
c. The area and growing stock of plantations of native and exotic species (a)
d. Annual removal of wood products compared to the volume determined to be sustainable (a)
e. Annual removal of nontimber forest products (e.g., fur bearers, berries, mushrooms, game) compared to the level determined to be sustainable (b)

Criterion 3: Maintenance of forest ecosystem health and vitality.

Indicators:

a. Area and percent of forest affected by processes or agents beyond the range of historic variation (e.g., by insects, disease, competition from exotic species, fire, storm, land clearance, permanent flooding, salinisation, and domestic animals) (b)
b. Area and percent of forest land subjected to levels of specific air pollutants (e.g., sulfates, nitrate, ozone) or ultraviolet B that may cause negative impacts on the forest ecosystem (b)
c. Area and percent of forest land with diminished biological components indicative of changes in fundamental ecological processes (e.g., soil, nutrient cycling, seed dispersion, pollination) and/or ecological continuity (monitoring of functionally important species such as nematodes, arboreal epiphytes, beetles. fungi, wasps, etc.) (b)

Criterion 4: Conservation and maintenance of soil and water resources.

This criterion encompasses the conservation of soil and water resources and the protective and productive functions of forests.

Indicators:

a. Area and percent of forest land with significant soil erosion (b)
b. Area and percent of forest land managed primarily for protective functions (e.g., watersheds, flood protection, avalanche protection, riparian zones) (a)
c. Percent of stream kilometers in for tested catchments in which stream flow and timing has significantly deviated from the historic range of variation (b)
d. Area and percent of forest land with significantly diminished soil organic matter and/or changes in other soil chemical properties (b)
e. Area and percent of forest land with significant compaction or change in soil physical properties resulting from human activities (b)
f. Percent of water bodies in forest areas (e.g., stream kilometers, lake hectares) with significant variance of biological diversity from the historic range of variability (b)
g. Percent of water bodies in forest areas (e.g., stream kilometers, lake hectares) with significant variation from the historic range of variability in pH, dissolved oxygen, levels of chemicals (electrical conductivity), sedimentation, or temperature change (b)

h. Area and percent of forest land experiencing an accumulation of persistent toxic substances (b)

Criterion 5: Maintenance of forest contribution to global carbon cycles.

Indicators:

a. Total forest ecosystem biomass and carbon pool, and if appropriate, by forest type, age class, and successional stages (b)

b. Contribution of forest ecosystems to the total global carbon budget, including absorption and release of carbon (standing biomass, coarse woody debris, peat and soil carbon) (a or b)

c. Contribution of forest products to the global carbon budget (b)

Criterion 6: Maintenance and enhancement of long-term multiple socioeconomic benefits to meet the needs of societies.

Indicators:

Production and consumption

a. Value and volume of wood and wood products production, including value added through downstream processing (a)

b. Value and quantities of production of nonwood forest products (b)

c. Supply and consumption of wood and wood products, including consumption per capita (a)

d. Value of wood and nonwood products production as percentage of GDP (a or b)

e. Degree of recycling of forest products (a or b)

f. Supply and consumption/use of nonwood products (a or b)

Recreation and tourism

a. Area and percent of forest land managed for general recreation and tourism, in relation to the total area of forest land (a or b)

b. Number and type of facilities available for general recreation and tourism, in relation to population and forest area (a or b)

c. Number of visitor days attributed to recreation and tourism, in relation to population and forest area (b)

Investment in the forest sector

a. Value of investment, including investment in forest growing, forest health and management, planted forests, wood processing, recreation, and tourism (a)

b. Level of expenditure on research and development, and education (b)

c. Extension and use of new and improved technology (b)

d. Rates of return on investment (b)

Cultural, social, and spiritual needs and values

a. Area and percent of forest land managed in relation to the total area of forest land to protect the range of cultural, social, and spiritual needs and values (a or b)

b. Nonconsumptive-use forest values (b)

Employment and community needs

a. Direct and indirect employment in the forest sector and the forest sector employment as a proportion of total employment (a or b)

b. Average wage rates and injury rates in major employment categories within the forest sector

c. Viability and adaptability to changing economic conditions, of forest-dependent communities, including indigenous communities (b)

d. Area and percent of forest land used for subsistence purposes (b)

SECTION 4: CRITERIA AND INDICATORS FOR THE CONSERVATION AND SUSTAINABLE MANAGEMENT OF TEMPERATE AND BOREAL FORESTS-CRITERION 7

Criterion 7 and associated indicators relate to the overall policy framework of a country that can facilitate the conservation and sustainable management of forests. Included are the broader societal conditions and processes often external to the forest itself but which may support efforts to conserve, maintain, or enhance one or more of the conditions, attributes, functions, and benefits captured in criteria 1-6. No priority or order is implied in the listing of the indicators.

Criterion 7: Legal, institutional, and economic framework for forest conservation and sustainable management.

Indicators:

Extent to which the legal framework (laws, regulations, guidelines) supports the conservation and sustainable management of forests, including the extent to which it

a. Clarifies property rights, provides for appropriate land tenure arrangements, recognizes customary and traditional rights of indigenous people, and provides means of resolving property disputes by due process;

b. Provides for periodic forest-related planning, assessment, and policy review that recognizes the range of forest values, including coordination with relevant sectors;

c. Provides opportunities for public participation in public policy and decisionmaking related to forests and public access to information;

d. Encourages best practice codes for forest management;

e. Provides for the management of forests to conserve special environmental, cultural, social, and/or scientific values.

Extent to which the institutional framework supports the conservation and sustainable management of forests, including the capacity to

a. Provide for public involvement activities and public education, awareness, and extension programs, and make available forest-related information;

b. Undertake and implement periodic forest-related planning, assessment, and policy review including cross-sectoral planning and coordination;

c. Develop and maintain human resource skills across relevant disciplines;

d. Develop and maintain efficient physical infrastructure to facilitate the supply of forest products and services and support forest management;

e. Enforce laws, regulations, and guidelines.

Extent to which the economic framework (economic policies and measures) supports the conservation and sustainable management of forests through

a. Investment and taxation policies and a regulatory environment which recognize the long-term nature of investments and permit the flow of capital in and out of the forest sector in response to market signals, nonmarket economic valuations, and public policy decisions in order to meet long-term demands for forest products and services;

b. Nondiscriminatory trade policies for forest products.

Capacity to measure and monitor changes in the conservation and sustainable management of forests, including

a. Availability and extent of up-to-date data, statistics, and other information important to measuring or describing indicators associated with criteria 1-7;

b. Scope, frequency, and statistical reliability of forest inventories, assessments, monitoring, and other relevant information;

c. Compatibility with other countries in measuring, monitoring, and reporting on indicators.

Capacity to conduct and apply research and development aimed at improving forest management and delivery of forest goods and services, including

a. Development of scientific understanding of forest ecosystem characteristics and functions;

b. Development of methodologies to measure and integrate environmental and social costs and benefits into markets and public policies, and to reflect forest-related resource depletion or replenishment in national accounting systems;

c. New technologies and the capacity to assess the socioeconomic consequences associated with the introduction of new technologies;

d. Enhancement of ability to predict impacts of human intervention on forests;

e. Ability to predict impacts on forests of possible climate change.

APPENDIX 4.

LUCID PILOT TEST INTERIM PRODUCTS AND TASKS

TIMING	DETAILS	PRODUCT/TASK
Briefing Meeting	Initial Core Team meeting with Forest Team biographies and contacts for the Core Team and to share with other forest teams.	• Draft Forest Team selected • Forest Team Bios
1st-2nd Joint Meeting	1st draft list of C&I modified from CORE set through first meetings	• 1st Draft C&I List
1 week after 1st-2nd Joint Meeting	Initial documentation (indicators form) in Access Database modified at the 1st-2nd joint meeting	• Access Database (P,C,I,V Evaluation)
Prior to 3rd Joint Meeting	Review of all C&I their frameworks completed in advance of the meeting	• C&I frameworks
	Preparation of approximately 50% of indicators through the verifier level (standards may not be identified yet) in Access Database	• Indicator & Verifier Evaluations
	Copy of communication plan if communication strategy is part of the LUCID Pilot (not all forests may engage in a public option)	• Communication Plan
3rd Joint Meeting On-site review by selected Core Team representative(s)	Review of all C&I (external review by other Core Team members as needed)	• 2nd Draft C&I List
	Documentation to date (P,C,I,V) in Access Database modified through the end of the 3rd meeting	• Access Database (P,C,I,V Evaluation)
2 weeks prior to 4th Joint Meeting	Evaluation of remaining indicators through the verifier level (submit to Core Team)	• Indicator & Verifier Evaluation
Prior to 4th Joint Meeting	Conceptual Model prepared by Core Team based on indicators/verifiers provided from the Forest Team	• Forest Sustainability Conceptual Model
	Construction of standards (as known) by Forest Team for each verifier	• Standards
4th Joint Meeting	1st Draft analytical model prepared by Core and Forest Teams during 4th meeting (the result of this model will be a final selection for testing of indicators and verifiers and a means of analyzing inter-relationships	• Analytical Model (1st Draft)
	Documentation to date (P,C,I,V) in Access Database modified as a result of the preparation of the conceptual and analytical models.	• Access Database (P,C,I,V Evaluation)
	3rd draft list of C&I	• 3rd Draft C&I List
1 month after 4th Joint Meeting **(Possible on-site review by some Core Team members as needed)**	Revision of Analytical Model by Forest Team (with help/advice from Core Team, as needed)	• Analytical Model (2nd Draft)
	Site visit by Core Team member(s) for review/advice regarding data collection and preparation for use in Netweaver	• Continued work on data collection
Between 4th and 5th Meetings	Data collection and analysis for confirmed indicators/verifiers (for which data is currently available). Data should be prepared and tested for use in the Netweaver Model with advance analysis done as needed.	• Data Collection & Analysis
	Revised (final) documentation within the Access Database modified as a result of the data collection stage.	• Access Database (P,C,I,V Evaluation)
By 5th Joint Meeting	Sustainability determination through examination of available data within the Forest Sustainability Analytical Model	• Sustainability Determination
5th Joint Meeting	Final review and testing of Forest Sustainability Analytical Model	• Analytical Model (3rd Draft)
	Review of final products of a sustainability determination	• Reporting Strategy

LUCID PILOT TEST FINAL PRODUCTS

Product	Details
First Approximation Report--Sustainability Determination	First year sustainability determination and identification of issues contributing to sustainable ecosystem management
C&I List	Final list of C&I
Access Database	Final version of the Access Database
Forest Sustainability Model	Conceptual and analytical model for the pilot produced through the Netweaver program
Communications Results	For those forest who engaged in public events or processes through LUCID, the Core Team would like a summary of the communications conducted, partnerships developed, and results
LUCID Evaluation	Team evaluation of the LUCID process (guidelines to be provided by Core Team)

APPENDIX 5.

THE OTTAWA LUCID PILOT PROCESS BY MAJOR PILOT TASK

1) REVIEW THE INITIAL LUCID CORE PCIV SET AND DELETE, MODIFY, OR ADD PCIV AS NEEDED TO FIT OTTAWA NATIONAL FOREST CONDITIONS

a) Create Ottawa Forest Team.
   i) Team includes Bob Brenner, Planner and Economist, Team Leader; Michelle Davalos, GIS Analyst and Data Steward; Sarah Mase, Soil Scientist and Terrestrial Ecologist; Bob Johnson, Wildlife Biologist; Sue Trull, Botanist/Plant Ecologist (initial team meeting 8/5/99).

b) Hold meeting with core team for project overview, to orient core team to Ottawa National Forest, and to discuss frameworks.
   i) Aug. 23-26, 1999, Ottawa Forest Team and core team, Forest Supervisor and selected Ottawa staff. Included field trip to orient core team and provide discussion of Ottawa issues.

c) Conduct general/initial review of PCIV set, note areas where we may need to adapt the generic set.
   i) Ottawa Forest Team working individually and with occasional team meetings (e.g., 9/23/99 team meeting (plus Steve Schlobohm, Forest management team representative) to discuss PCIV; 10/4-7 meetings with Ottawa team and national team) and conference calls with core team members.

d) Hold public meetings with other "Partners in Monitoring", and with area tribal and local government officials to discuss the project and hear their ideas on criteria, indicators, and sustainability.
   i) Oct. 7, 1999, Ottawa Forest Team, selected Ottawa staff, some of core team, and various invitees
   ii) Planned second meeting with general public- not held for various reasons

e) Review sets of C&I from other sources (e.g., Great Lakes Forestry Assessment, Gogebic County etc)
   i) Ottawa Forest Team working individually on indicator review.

f) Refine our set with evaluation form provided by core team, checking whether indicators meet Tropenbos hierarchy, whether indicator is applicable to the Ottawa, assessing data availability and quality, etc.
   i) Ottawa Forest Team working individually and with occasional team meetings and conference calls with core team members.
   ii) Enter evaluation results into Access database and Word documents per core team direction.

g) Meet with our sister forest (Blue Mountains) and national team to share ideas and review each other's PCIV sets.
   i) May 23-25, 2000 in Baker City, Oregon (introduction to Netweaver).
   ii) November 6-9, 2000 in Ironwood (introduction to GeoNetweaver).

h) Further review our set by developing conceptual model, considering linkages and overlaps.
   i) Ottawa Forest Team working individually and with occasional team meetings and conference calls with core team members.

i) Seek input and review of our PCIV set from local experts (outside Ottawa Forest Team, but within Ottawa NF, Regional Office, and North Central Research Station) and core team.

- Ottawa Forest Team working individually and in subgroups (e.g., ecology group of Mase, Johnson, Trull; economic/social group of Brenner and Davalos).
- Ottawa Forest Team meets with core team members Pam Wright, Brent Tegler and Buddy Stewart on different workdays.

➠ Finalize PCIV set including standards.

➠ Finalize Netweaver conceptual model and modify to analytical model.

2) APPLY CRITERIA AND INDICATORS TO MEASURE SUSTAINABILITY

➠ Assess data availability for each verifier/data element in final set, provide data values where available, gather data in limited cases, retain missing-data verifiers and data elements as placeholders for future data gathering.

- Ottawa Forest Team working individually and with occasional team meetings.

➠ Develop database to hold values and to be input file for Netweaver.

- Enter data element values into Excel spreadsheet
- Determine map extents for each verifier or data element and set up shape files for GeoNetweaver (with assistance from Bruce Miller in developing overlay files)

➠ Modify database and Netweaver model to accommodate software changes and development of GeoNetweaver.

- Core team plus Bruce Miller, Netweaver/GeoNetweaver developer, did much of this during November 2000 meeting.

➠ Use GeoNetweaver to conduct spatial analyses.

- Primarily Michelle Davalos, GIS specialist on Ottawa Forest Team.

➠ Use Netweaver model and data value spreadsheets to further analyze PCIV and whether standards were met for the Ottawa.

- Ottawa Forest Team working individually and with occasional team meetings.

3) REPORT ON SUSTAINABILITY TO IMPROVE FOREST MANAGEMENT (VOL. 2 REPORT)

➠ Provide and interpret results for Ottawa employees and management team, and WO representatives.

➠ Provide and interpret results for Partners in Monitoring and general public.

➠ Summarize results and interpretations for core team.

4) REVIEW THE EFFECTIVENESS OF USING CRITERIA AND INDICATORS TO MEASURE SUSTAINABILITY (VOL. 1 REPORT)

➠ Summarize utility and effectiveness for Ottawa management team.

➠ Summarize utility and effectiveness for core team.

A series of discussion meetings and presentations about the LUCID Project and the Ottawa's were given at various points during the project. These discussions included R9 forest planners, NE Resource Planners Association, resource management classes at MTU. These discussions helped to acquaint others with the project and also provided us with valuable ideas and questions to use in our continuing work.

APPENDIX 6.

INITIAL LUCID C&I LIST AND SOURCE COMPARISON

LUCID Initial Criteria	LUCID Initial Core C&I	CIFOR - NA (Boise)	Montreal Process	CCFM
C1.1 Spiritual and cultural values	1.1.1 Wilderness		43. Non-consumptive use forest values	3.2.3 Area, percentage and representativeness of forest types in protected areas
	1.1.2 Aboriginal and non-Aboriginal cultural, spiritual, social sites/values	3.4.3 Extent to which forest management planning takes into account the protection of unique or significant aboriginal social, cultural, or spiritual sites	42. Area and percent of forest land managed in relation to the total area of forest land to protect the range of cultural, social and spiritual needs and values / 52. Provides for the management of forests to conserve special environmental, cultural, social and/or scientific values	6.2.2 Extent to which forest management planning takes into account the protection of unique or significant Aboriginal social, cultural or spiritual sites
C1.2 Aesthetic values	1.2.1 Scenery		43. Non-consumptive use forest values	
C1.3 Recreational values	1.3.1 Recreational, tourism and education opportunities (by activity)	2.4.1 Availability and use of recreational opportunities are maintained	35. Area and percent of forest land managed for general recreation and tourism, in relation to the total area of forest land / 36. Number and type of facilities available for general recreation and tourism, in relation to population / 37. Number of visitor days attributed to recreation and tourism, in relation to population and forest area. / 43. Non-consumptive use forest values	5.4.1 Availability and use of recreational opportunities
C1.4 Access	1.4.1 Access to forest resources	3.1.1. Access to forest resources is perceived to be fair and secure		

LUCID Initial Criteria	LUCID Initial Core C&I	CIFOR - NA (Boise)	Montreal Process	CCFM
	1.4.2 Ownership and use rights	3.1.2 Ownership and use rights and responsibilities to resources are clear and respect preexisting claims	48. Clarifies property rights, provides for appropriate land tenure arrangements, recognizes customary and traditional rights of indigenous people, and provides means of resolving property disputes by due process	6.1.1 Extent to which forest planning and management processes consider and meet legal obligations with respect to duly established Aboriginal and treaty rights
C1.5 Involvement values	1.5.1 Participation/involvement in decision making	3.2.1 The process should be inclusive with all interests represented / 3.2.2. Stakeholders should have detailed and meaningful reciprocal background information necessary to provide quality input into the public participation process / 3.2.3. Management staff and stakeholders should recognize and respect the interests and rights of each other / 3.2.4 The decision making processes must be transparent such that participants are confident that their opinions and values will be considered during the process and be reflected in the final product	50. Provides opportunities for public participation in public policy an decision making related to forests and public access to information	6.4.2 Degree of public participation in decisionmaking processes / 6.4.1 Degree of public participation in the design of the decisionmaking processes / 6.4.3 Degree of public participation in implementation of decisions and monitoring of progress toward SFM / 6.5.4 Percentage of forest area under comleted management plans that have included public participation

LUCID Initial Criteria	LUCID Initial Core C&I	CIFOR - NA (Boise)	Montreal Process	CCFM
C1.6 Forest-based human health values	1.6.1 Worker health and safety	3.3.2 Forestry employers follow ILO working and safety conditions and take responsibility for the forest-related health risks of workers	45. Average wage rates and injury rates in major employment categories within the forest sector.	
	1.6.2 Public health and safety	3.3.1 Forest managers cooperate with public health authorities regarding illnesses relted to forest management and potable water related concerns		
C1.7 Gathering (non-economic) forest values	1.7.1 Subsistence and non-subsistence gathering	3.4.4. Area of forest land available for subsistence purposes	47. Area and percent of forest land used for subsistence purposes	6.2.4 Area of forest land available for subsistence purposes
C.2.1 Landscape function	I.2.1.1 Hydrologic condition			
	I.2.1.2 Disturbance processes	1.1.3 Area and severity of area burned / 1.1.4 Area and severity of insect attack and disease infestation	15. Area and percent of forest affected by processes or agents beyond the range of historic variation (e.g., by insects, disease etc)	2.1.3 Area and severity of area burned / 2.1.1 Area and severity of insect attack / 2.1.2 Area and severity of disease infestation

LUCID Initial Criteria	LUCID Initial Core C&I	CIFOR - NA (Boise)	Montreal Process	CCFM
C.2.2 Landscape structure	I.2.2.1 Vegetation types and structural classes	1.3.1 Percentage and extent, in area, of vegetation types and structural classes relative to the historical condition and total forest area / 1.4.2 Rate and total area of forest land converted to nonforest land cover, classed by major forest type	1. Extent of area by forest type relative to total forest area / 2. Extent of area by forest type and by age class or successional stage	1.1.1 Percentage and extent, in area, of forest types relative to the historical condition and total forest area / 1.1.2 Percentage and extent of area by forest type and age class / 4.2.1 Area of forest permanently converted to nonforest land use / 4.2.2 Semipermanent or temporary loss or gain of forest ecosystems / 3.1.2 Area of forest converted to nonforest land use
	I.2.2.2 Linear features	1.2.2. Road network density, type, use and location		3.2.2 Percentage of forested area having road construction and stream crossing guidelines in place / 3.1.2 Area of forest converted to nonforest land use
	I.2.2.3 Fragmentation and connectedness	1.2.1 Level of fragmentation and connectedness of forest ecosystem components	5. Fragmentation of forest types	1.1.4 Level of fragmentation and connectedness for forest ecosystem components
	I.2.2.5 Water quality e.g., dissolved oxygen, suspended sediments and water nutrients		24. Percent of water bodies in forest areas with significant variations from the historica range of variability of pH, dissolved oxygen, levels of chemicals, sedimentation or temperature change	3.1.3 Water quality as measured by water chemistry, turbidity

LUCID Initial Criteria	LUCID Initial Core C&I	CIFOR - NA (Boise)	Montreal Process	CCFM
C.2.3 Ecosystem function	I.2.3.1 Nutrient cycling		17. Area and percent of forest land with diminised biological componets indicated of changes in fundamental ecological processes (e.g., soil nutrient cycling)	
	I2.3.2 Primary productivity	2.2.6 Mean annual increment for forest type and age class	26. Total forest ecosystem biomass and carbon pool, and if appropriate, by forest type, age class, and successional stages	2.3.1 Mean annual increment by forest type and age class / 4.1.1 Tree biomass volumes / 4.1.2 Vegetation (no-tree) biomass estimates / 4.1.3 Percentage of canopy cover / 4.1.4 Percentage of biomass volume by general forest type
C.2.4 Ecosystem structure	I.2.4.1 Pollutants	1.5.1 Pollutant levels in the ecosystem	16. Area and percent of forest land subjected to levels of specific air pollutants / 25. Area and percent of forest land experiencing an accumulation of persistent toxic substances	2.1.4 Rates of pollutant deposition / 2.1.5 Ozone concentrations in forested regions
	I.2.4.2 Soil quality e.g., soil compaction, displacement, erosion, puddling, loss of organic material	1.7.1 Percentage of harvested area having greater than 25% of the area with degraded soil quality	18. Area and percent of forest land with significant soil erosion / 21. Area and percent of forest land with significantly diminshed soil organic matter and/or changes in other soil chemical properaties / 22. Area and perent of forest land with significant compaction or change in soil physical properties	3.1.1 Percentage of harvested area having significant soil problems

LUCID Initial Criteria	LUCID Initial Core C&I	CIFOR - NA (Boise)	Montreal Process	CCFM
	I.2.4.3 Soil nutrients		17. Area and percent of forest land with diminised biological componets indicated of changes in fundamental ecological processes (e.g., soil nutrient cycling)	
	I.2.4.4 Ecological legacies and structural elements	1.1.2 Coarse woody debris and snags retained at functional levels		
	I.2.4.5 Ecologically sensitive areas, e.g., riparian areas are retained	1.1.1 Ecologically sensitive areas, especially buffer zones along water courses, are protected	19. Area and percent of forest land managed primarily for protective functions. E.g., watersheds, riparian zones / 52. Provides for the management of forests to conserve special environmental, cultural, social and/or scientific values	
	I.2.4.6 Morphology and function of stream channels		20. Percent of stream km in forested catchments in which stream flow andtiming has significantly deviated from the historic range of variation	3.1.4 Trends and timing of events in stream flows from forest catchments
C.2.5 Population function	I.2.5.1 Populations of indigenous species	1.3.2 Populations of indigenous species are likely to persist / 1.3.4 Assessment of changes in the distribution and abundance of native aquatic fauna	6. The number of forest dependent species	1.2.2 Population levels and changes over time for selected species and species guilds / 2.3.2 Frequency of occurrence within selected indicator species / 3.1.5 Changes in the distribution and abundance of aquatic fauna

LUCID Initial Criteria	LUCID Initial Core C&I	CIFOR - NA (Boise)	Montreal Process	CCFM
C.2.6 Population structure	I.2.6.1 Exotic species	1.5.2 Area and severity of occurrence of exotic species detrimental to forest conditions	12. The area and growing stock of plantations of native and exotic species	2.1.7 Area and severity of occurrence of exotic species detrimental to forest condition
	I.2.6.2 Community guild structure	1.4.3 Representation of selected key and sensitive guilds occur in the community guild structure		
	I.2.6.3 Species at risk	1.3.3. Number of known forest-dependent species classified as extinct, extirpated, endangered, threatened, or vulnerable relative to the total number of known forest dependent species	7. The status of forest dependent species at risk of not maintaining viable breeding populations, as determined by legislation or scientific assessment	1.2.1 Number of known forest-dependent species classified as at risk
C.2.7 Genetic function	I.2.7.1 Gene frequencies change			
	I.2.7.2 Minimum viable populations			

LUCID Initial Criteria	LUCID Initial Core C&I	CIFOR - NA (Boise)	Montreal Process	CCFM
C.2.8 Genetic structure	I.2.8.1 Non-native or enhanced stock	1.6.1 Population sizes and reproductive success are adequate to maintain levels of genetic diversity / 1.6.2 Use of scientifically-based seed transfer rules and seed orchard zones in planting native species / 1.6.3 Management does not significantly change gene frequencies	8. Number of forest dependent species that occupy a small portion of their former range / 9. Populatoin levels of representative species from diverse habitats monitored across their range.	2.2.2 Percentage of area successfully naturally regenerated and artificially regenerated
C3.1 Wealth and capital accumulation	3.1.1 Community economic trade balance (imports and exports)			
	3.1.2 Land base available for production	2.2.7 Distribution of, and changes in, the land base available for timber production are identified	10. Area of forest land and net area of forest land available for timber production / 11. Total growing stock of both merchantable and nonmerchantable tree species on forest land available for timber production	5.1.2 Distribution of, and changes in, the landbase available for timber production
C3.2 Production and consumption considerations	3.2.1 Annual and periodic removals of products (timber and non-timber)	2.2.5 Annual and periodic removals calculated by area or volume prescribed	13. Annual removal of wood products compared to the volume determined to be sustainable / 14. Annual removal of nontimber forest products compared to the level determined to be sustainable	5.1.1 Annual removal of forest products relative to the volume of removals determined to be sustainable / 5.3.3 Utilization of forests for nonmarket goods and services, including forest land use for subsistence purposes

LUCID Initial Criteria	LUCID Initial Core C&I	CIFOR - NA (Boise)	Montreal Process	CCFM
	3.2.3 Money spent by visitors in local communities (by activity)	2.4.2 Total expenditures by individuals on activities related to nontimber use		5.4.2 Total expenditures by individuals on activities related to nontimber use
	3.2.4 Value to products including value-added through downstream processing		29. Value and volume of wood and wood products production, including value added through downstream processing / 30 Value and quantities of non-wood forest products	
	3.2.5 Resource production component	3.5.5 Number of communities with a significant forestry component in the economic base	46. Viability and adaptability to changing economic conditions, of forest dependent communities, including indigenous communities	6.3.1 Number of communities with a significant forestry component in the economic base
	3.2.6 Income from National Forest activities	3.5.2 Wages and other benefits conform to national or ILO standards	45. Average wage rates and injury rates in major employment categories within the forest sector.	
	3.2.7 Employment of local population in resource management	3.5.3 Employment of local population in forest management	44. Direct and indirect employment in the forest sector and the forest sector employment as a proportion of total employment	5.3.2 Total employment in all forest-related sectors
C3.3 Trade and distribution considerations	3.3.1 Rent capture	2.4.3 Existence of economic rents: Total harvesting revenues exceed harvesting costs / 3.5.4 Estimated distribution of rent capture	41. Rates of return on investment	5.2.1 Net profitability
	3.3.2 Mechanisms economic benefits sharing	3.5.1 Mechanisms exist for sharing the economic benefits derived from forest management		
	3.3.3 Community economic diversity		46. Viability and adaptability to changing economic conditions, of forest dependent communities, including indigenous communities	6.3.2 Index of the diversity of the local industrial base

[illegible]	NO LUCID EQUIVALENT	NO LUCID EQUIVALENT	NO LUCID EQUIVALENT	NO LUCID EQUIVALENT
Protection		1.3.1 Protected areas are maintained to protect rare, unique and representative species and features	3. Extent of area by forest type in protected area categories as defined by IUCN or other classification systems / 4. Extent of areas by forest bype in protected areas defined by age class or successional stages	2.3.1 Mean annual increment by forest type and age class / 1.1.3 Area, percentage and representativeness of forest types in protected areas / 3.2.1 Percentage of forest managed primarily for soil and water protection / 5.4.4 Area and percentage of protected forest by degree of protection
Funding		2.1.1 Effective instruments for interinstitutional coordination on land use and forest management exist		
		2.1.2 There is sustained and adequate funding and staff for the management of forests	38. Value of investment in forest growing, including investment in forest growing	5.1.4 Management and development expenditures
		2.1.3 Institutions responsible for forest research are adequately funded and staffed	39. Level of expenditure on research and development , and education	6.5.2 Investments in forest-based research and development and information

	NO LUCID EQUIVALENT	NO LUCID EQUIVALENT	NO LUCID EQUIVALENT	NO LUCID EQUIVALENT
Planning and Management		2.2.2 Objectives are clearly stated in terms of the major functional areas of the forest with respect to their spatial distribution		
		2.2.3 Silvicultural systems are prescribed as appropriate to forest type, production of desired products and condition, and ensure forest establishment, composition and growth		
		2.2.4 Harvesting systems and equipment are presecribed to match forest conditions in order to reduce impact on wildlife, soil productivity, residual stand conditions and water quality and quantity		
				3.2.2 Percentage of forested area having road construction and stream crossing guidelines in place
		2.2.6 Mean annual increment for forest type and age class		
		2.3.1 Actual vs. planned performance is measured and recorded		2.3.1 Mean annual increment by forest type and age class

	NO LUCID EQUIVALENT	NO LUCID EQUIVALENT	NO LUCID EQUIVALENT	NO LUCID EQUIVALENT
Monitoring		2.3.2 An effective monitoring and control system audits management's conformity with planning	49. Provides for periodic forest-related planning, asessment and policy review / 60. Availability and extent of up-to-date data, statistic and information important to measuring or describing indicators / 61. Scope, frequency and statistical reliability of forest inventories, assessments, monitoring and other relevant information	
		2.2.1 Planning and policy are based on recent and accurate information		
		2.3.3 Continuous inventories established and measured regularly	60. Availability and extent of up-to-date data, statistic and information important to measuring or describing indicators / 61. Scope, frequency and statistical reliability of forest inventories, assessments, monitoring and other relevant information	4.4.4 Existence of forest inventories / 6.5.1 Percentage of area covered by multiattribute inventories
		2.3.4 Documentation and records of all forest management activities are kept in a form that makes monitoring possible		
			54. Undertake and implement periodic forest-related planning, assesment and policy review	

	NO LUCID EQUIVALENT	NO LUCID EQUIVALENT	NO LUCID EQUIVALENT	NO LUCID EQUIVALENT
			62. Compatibility with other countries in measuring, monitoring and reporting on indicators	
			63. Development of scientific understanding of forest ecosystem characteristics and functions	
Stewardship / Management				6.3.4 Number of communities with stewardship or comanagement responsibilities
				6.2.5 Area of Indian reserve forest lands under integrated management plans
Rights and Responsibilities		3.4.1 Extent to which forest planning and management processes consider and meet legal obligations with respect to duly established aboriginal and treaty rights		6.1.1 Extent to which forest planning and management processes consider and meet legal obligations with respect to duly established Aboriginal and treaty rights
		3.4.2 Assess the extent of aboriginal participation in forest-based opportunities		6.2.1 Extent of Aboriginal participation in forest-based economic opportunities / 6.2.3 Number of Aboriginal communites with a significant forestry component in the economic base and diversity of forest use at the community level

	NO LUCID EQUIVALENT	NO LUCID EQUIVALENT	NO LUCID EQUIVALENT	NO LUCID EQUIVALENT
				6.5.6 Mutual learning mechanisms and processes
				6.5.5 Expenditures on international forestry
Laws and Regulations			57. Enforce laws, regulations and guidelines	4.4.5 Existence of laws and regulations on forest land management
			51. Encourages best practice codes for forest management	
Public Education			53. Provide for public involvement activities and public education, awareness and extension programs, and make available forest related information	6.5.3 Total effective expenditures on public forestry education
				6.3.3 Diversity of forest use at the community level
				5.4.3 Memberships and expenditures in forest recreation-oriented organizations and clubs
Climate / Carbon				2.1.8 Climate change as measured by temperature sums
			27. Contribution of forest ecosystems to the total global carbon budget, including absorption and release of carbon	4.1.5 Soil carbon pools
				4.1.6 Soil carbon pool decay rates
				4.1.7 Area of forest depletion
			28. Contribution of forest products to the global carbon budget	4.1.8 Forest wood product life cycles

	NO LUCID EQUIVALENT	NO LUCID EQUIVALENT	NO LUCID EQUIVALENT	NO LUCID EQUIVALENT
				4.1.9 Forest sector carbon dioxide emissions
				4.3.1 Fossil fuel emissions
				4.3.2 Fossil carbon product emissions
				4.3.3 Percentage of forest sector energy usage from renewable sources relative to the total energy sector requirement
			33. Degree of recyling of forest products	4.4.1 Recycling rate of forest wood products manufactured and used in Canada
				4.4.2 Participation in the climate change conventions
				4.4.3 Economic incentives for bioenergy use
			67. Ability to predict impacts on forests of possible climate change	
Economic Indicators				5.1.5 Availability of habitat for selected species of economic importance
				5.2.2 Trends in global market share
				5.3.1 Contribution of timber and nontimber sectors to the gross domestic product
				5.3.4 Economic value of nonmarket goods and services
Trade / Market			58. Investment and taxation policy and a regulatory environment which recognizes the long-term nature of investments	

	NO LUCID EQUIVALENT	NO LUCID EQUIVALENT	NO LUCID EQUIVALENT	NO LUCID EQUIVALENT
			59. Non-discriminatory trade policies for forest products	
			31. Supply and consumption of wood and wood products	
			34. Supply and consumption/use of non-wood products	
Ecological Indicators				1.2.3 Number of known forest-dependent species that occupy only a small portion of their former range
				1.3.1 Implementation of an in situ/ex situ genetic conservation strategy for commercial and endangered forest vegetation species
				4.5.1 Surface area of water within forested areas
				5.1.3 Animal population trends for selected species of economic importance
			23. Percent of water bodies in forest areas with significant variance of biological diversity from the historic range of variability	
				2.1.6 Crown transparency in percentage by class
			40. Extension and use of new and improved technology	5.2.3 Trends in research and development expenditures in forest products and processing technologies

	NO LUCID EQUIVALENT	NO LUCID EQUIVALENT	NO LUCID EQUIVALENT	NO LUCID EQUIVALENT
Other			64. Development of methodologies to measure and integrate environmental and social costs and benefits into markets and public policies	
			65. New technologies and capacity to assess the socioeconomic consequences associated with the introduction of new technologies	
			66. Enhancement of ability to predict impacts of human intervention on forests	
			55. Develop and maintain human resource skills across relevant disciplines	
	efficiency?		56. Develop and maintain efficient physical infrastructure to facilitate the supply of forest products and services and support forest management	

APPENDIX 7.

INDICATOR AND VERIFIER DEVELOPMENT FORM[1]

INDICATOR FORM (ACCESS DATABASE)

Original Name. The wording for the indicator should correspond with the wording in the original core set of C&I.

New Name/Final Name. Please make the revisions to the indicator name here.

Reasons for Name Change: Explanation of what kind of changes made and why

> *The explanation should state whether the wording change is a "substantive change" or merely a "word choice" or "language change" that has been done to make the indicator language more in keeping with what your forest is familiar with. Obviously there is a desire to retain a generic wording for the indicators if possible so that they might be applicable to other testing locations in Mexico, however, the indicator selection process is flexible and can cope with both "minor" and "substantive" changes.*
>
> *If you have proposed a NEW indicator please indicate that here.*

Definition. This section should include a basic definition of the indicator title including the terms/words used in final wording of the Indicator. This is intended to be a detailed description of the indicator. The definition should not however, be specific to any given methodology for data collection.

> *As the indicator wording is generally short, a longer definition is useful to define the indicator in a way that everyone will understand. Individual words or phrases may be explained more fully. Try to keep methodology out of your definition. You may want to provide an example following the definition, however that gives some of the local examples or issues that would be contained within the indicator. If you want to illustrate the definition with some examples of things you would focus on in your area (e.g., for Ecological legacies the Ejido El Largo might list: snags and coarse woody debris).*

Tropenbos. Forests were asked to check to see if the indicators met the following conditions—if they did then they got simply a yes.

---

[1] This form is designed to correspond with the Access database. Questions are numbered according to the database.

Non-Directional. Indicators should be written non-directionally that is they should be neither positive nor negative in their wording. For example, an indicator worded simply as "employment" or "local employment" is non-directional since it doesn't imply whether the desired state is an increase or a decrease in employment. This direction, which may change over time, will be set in the standard.

No Methods in Wording. As in the example above, the indicator wording should not include the measurement methods since you might use a variety of different methods to assess the indicator. The measurement method will be spelled out in the verifier section. Good example: Local employment. Bad example: Total number of full-time employees at the Ejido.

No Standard in Wording. No standard or benchmark against which the indicator should be judged should be contained within the indicator wording. The standard (e.g., '< 5 percent' soil compaction) will be specified later in the process and attached specifically to the verifier.

Underlying Concepts. In this section you may want to describe in more detail the underlying concepts for the Indicator including how it relates to sustainability and why you choose it—why it is important to measure this indicator. You may also need to explain how it relates to the criterion it is associated with.

- What are the theoretical foundations for the indicator?
- How is the indicator related to sustainable ecosystem management?

Linkages. How is the Indicator related to other indicators?

Here we would like you to identify some of the most critical linkages between this indicator and all the other related indicators—in particular you might want to focus on indicators that may share a common piece of data

Scale. At what scale do you think the indicator is best suited to tell something about sustainability? If the indicator can be used, as it is, at more than one scale please check all of the boxes.

Applicability to Other Locations. Do you think that this indicator could be used to measure sustainability at other sites in the United States.

You might want to look at your indicator wording and see if a minor change in the wording might make it more applicable elsewhere. For example, an indicator that was worded as 'forest fragmentation' might not work across ecosystems that are characterized naturally by open grasslands or rangeland. You might want to simply word the indicator as 'fragmentation' and then it could be applied to either forested or non-forested ecosystems both of which are subject to fragmentation.

Comments. Please put any notes or comments in this box. You might use this to remind yourself of the further work you need to do on this indicator.

VERIFIER DATABASE

Describe verifiers (measurement methods) for the indicator. (Note: more than one verifier may be included, the questions below should be used as guide to evaluate the available methodologies.)

Title/Name and Definition

Overall Method Description

Various specialists should be consulted to determine the available methods for indicators. The method or methods you suggest may be specific to your forest. Where possible select a method that is common among national forests in order to permit data aggregation.

- Are data collection methods well documented and commonly accepted?
- Are protocols proxy measures of the indicator or direct measures?
- What units are used for data collected?

Data Quality

(Note: where more than one data collection method has been described highlight differences in data quality)

- Sensitivity to change (signal to noise ratio high)
- Trend/Threshold detection
- Repeatable (high precision in data collection)
- Accurate (limited chance for false readings)

Data Needs

- Is specialized knowledge required for data collection?
- Is specialized equipment required for data collection?
- Is data easily analyzed?
- Is data easily communicated and presented?

Data Availability

This is a quick analysis of what is already available from existing or past monitoring programs, or inventories, etc. that fits or covers off part of this indicator. If you have a similar or related indicator this may lead you to re-examine the LUCID indicator in order to take advantage of an existing data set. Consider the implications of using an existing indicator to replace a LUCID indicator.

- Is comparable data available?
- How many years of available data are there?
- How many locations are there where data is collected?
- Have base line conditions been established?
- Has trend analysis been completed?

Data Sources

Who else is involved, or might be involved, in monitoring this indicator?

- What other organizations/agencies do/may have existing related monitoring programs?

What other organizations/agencies could be involved in cooperative monitoring?

- Who has the data/key contacts?

Development Needs

- Methodological or analytical needs for verifier development

Standards or Benchmarks

Standards may be either absolute thresholds (e.g., for potable water health organizations have set absolute thresholds for fecal coliform of no more than X parts per million) or, more often, ranges (e.g., in ecotype9 CWD between 15 and 25 pieces of class A CWD). In other situations you may in fact have several ranges for example associated with a Low, Medium and High scenario. It is entirely possible that you won't know the absolute numbers that ought to fit on a standard but you might be able to give a good estimate of when there is too little of something or alternately too much. If for example you were constructing a standard for the minimum viable population of elk you might be able to suggest than anything below 85 mature breeding elk would be too little (85 being an estimate), with between 150-250 elk the optimal number of elk for your unit of interest and anything over 350 being a population that is approaching hyperabundance. This 'distribution' is a very useful kind of standard to construct and is probably one of the easier ways when you don't know absolute numbers but know what the ends of the spectrum look like.

Source for the Standard

Standard (Benchmark) Range

(describe it as in the examples above with as much details). If there are different options put them all in and indicate the most preferred, second preferred standard.

- Absolute standard
- Range
- Distribution

Scale of Measurement

What are the scales that are relevant for this verifier (each part of this question is important):

1. What scale is the verifier measured at (e.g., if this is a field inventory of Coarse Woody Debris is it collected at the stand level sampling across a range of ecosystem types?—if this verifier is collected through a survey of public values is the scale of measurement the greater region (e.g., communities within and outside of the forest) or is it community by community?
2. At what scale does it make sense to report/analyze this verifier (e.g., community by community or just as one region including the forest within it)? Think about the original questions you are asking about this indicator to help here.
3. If the scale in 1 and 2 differ—how is the data for the verifier aggregated 'up' to answer question 2. What method (statistic even) of aggregation would you use (e.g., average CWD across the forest or standard deviation of CWD for each ecosystem type).

Antecedent Information

What other information do you need in order to assess this verifier (be specific)? E.g., for the CWD example in question 16 you would need an inventory of ecosystem types (e.g., Ecosection polygons).

Preferred Methods

If there is more than one method for collecting data for the indicator (e.g., multiple optional verifiers) please indicate which verifier is preferred and which is less preferred. This scenario might arise for example if you are able to write the optimal verifier but realize that in the short term (perhaps the first few years) you won't be able to use that verifier because of the cost of special equipment, or the availability of data or something. In this case you might come up with an alternative (but less preferred) or proxy verifier.

1. Preferred verifier
2. Next most preferred
3. Next most preferred

References

(Note: include all relevant references that will help others understand this indicator)

APPENDIX 8. LUCID TEAM DESCRIPTIONS

IMI CORE TEAM

The core team was composed of team leader Pamela Wright, Ph.D., a sociologist and ecologist; Brent Tegler, Ph.D., a terrestrial ecologist; Walter "Buddy" Stewart, Ph.D., an economist; Matt Turner, an analyst; and Greg Alward, Ph.D., an economist and ecologist. Although the core team had the necessary disciplinary expertise, its one weakness was the lack of a Geographic Information Systems (GIS) specialist early in the pilot process. Andy Peavy, a GIS analyst from IMI, was added to the core team near the end of the project when most pilot tests had reached the data modeling/sustainability assessment stage. Tom Hoekstra, Ph.D., the IMI director, provided support to the core team throughout the process, particularly on theoretical issues, and worked closely with the LUCID forest supervisors group and in liaison with other Forest Service initiatives. Eliaabeth Reite, a graduate student from Colorado State University, joined the team during the later stages of the process; she specifically helped on database management and development for the C&I list.

A number of other individuals assisted the core team throughout the LUCID pilot process. Additionally, Richard Phillips, USFS Region-6 Regional Economist assisted the core team, particularly in the formative stages of the LUCID Project as well as to the Blue Mountains, Modoc, and Mt. Hood teams. Bob Lee, IMI staff member, assisted in the examination of overlap between LUCID indicators and corporate data sets. Rich Hagestedt, analyst for Mt. Hood National Forest and the Mt. Hood LUCID team, helped resolve technical and analytical issues including model and database construction and display. Ancillary to the core team was the software development team, Bruce Miller and Mike Saunders, from Rules-of-Thumb, Inc. In addition to software development and modification, Bruce participated with the team in the final stages of the testing process associated with modeling and analysis. Lynette Morelan from Boise National Forest (BNF), and BNF liaison for the CIFOR-NA test, served as an advisor to the LUCID Project. Following the CIFOR-NA test, Lyn remained involved by implementing a sustainability monitoring approach for the South-West Idaho Eco-Group Forest Plan revision, built on the CIFOR-NA and preliminary LUCID experiences. Henry Lachowski and others at the USFS Remote Sensing Applications Group (RSAC) provided specific expertise on the potential of remote-sensing technologies for monitoring. A number of the LUCID forest team leaders and LUCID forest supervisors or their representatives served in review or presentation capacities for the LUCID core team. For example Robert Brenner, Ottawa National Forest LUCID Team Leader and Forest Planner not only gave several presentations on behalf of the LUCID core team but also reviewed and provided insightful comments on several sections as the report writing progressed.

Forest Team Participants

Ottawa National Forest Team

- Robert Brenner
- Bob Johnson
- Michelle Davalos
- Susan Trull
- Sarah Mase

Allegheny National Forest Team

- Jim Apgar
- Wendell Wallace
- Grace Wang
- Marc McDill
- Michael Jacobson
- Charles Strauss
- Dave DeCalesta
- Gary Kell
- Kathe Frank
- William Moriarity
- Flory & Linje Nankhuni

Blue Mountain Province Forest Team including participants from the:
Umatilla National Forest
Wallowa-Whitman National Forest
Malheur National Forest

- Kathleen Countryman
- Elaine Kohrman
- Caty Clifton
- Linda McEwan
- Mark Loewen

Modoc National Forest Team

- Sydney Smith
- Max Creasy
- Candace Dillingham

Mt. Hood National Forest Team

- Nancy Lankford
- Richard Hagestedt
- David Ervin
- Craig Shinn
- Cynthia Froyd
- Alex Miller
- Mathew Ives
- John Westerman

Tongass National Forest Team

- Karryl Krieger
- John Day
- Michael Shephard
- Cole Crocker-Bedford
- Robert Huecker
- Guy Robertson
- Gary Fisher

APPENDIX 9.

LUCID C&I RESOURCE DATABASE

LOCATED ON CD ONLY!

APPENDIX 10. FINAL SUITE OF LUCID PRINCIPLES, CRITERIA, INDICATORS AND MEASURES

Principle P1: Social Well-being

CRITERION	INDICATOR	MEASURE--RECOMMENDED	MEASURE--OPTIONS
C1.1 Collaborative stewardship	I1.1.1 Contribution of local and traditional and ecological knowledge	M1.1.1.1 Projects with traditional ecological knowledge/local knowledge component (e.g., number of projects)	
			MO1.1.1.2 Participation in traditional ecological knowledge workshops (number workshops, person hours participation)
C1.1 Collaborative stewardship	I1.1.2 Collaborative decision-making	M1.2.1 Projects done collaboratively (e.g., number of projects)	MO1.1.2.1 Assessment of Memo of Understand/Memo of Agreement and other agreements (e.g., number of agreements)
		M1.1.2.2 Participation in public review opportunities (e.g., number, representativeness, satisfaction with)	
			MO1.1.2.3 Environmental Assessment/Environmental Impact Statements resulting in appeals/lawsuits (e.g., number or proportion resulting in appeals)
			MO1.1.2.4 Requests for participation in decision making beyond requirements (e.g., number by type)
C1.1 Collaborative stewardship	I1.1.3 Stewardship activities	M1.1.3.1 Participation in stewardship activities (e.g., number of volunteer days, number of individuals involved)	MO1.1.3.1 Cooperative stewardship initiatives (e.g., number of initiatives by type)
			MO1.1.3.2 Partnership contributions (e.g., dollars, in-kind contributions, cost shares)
C1.1 Collaborative stewardship	I1.1.4 Local area empowerment and development	M1.1.4.1 Skill base development and retention (e.g., number of training hours, days, sessions)	
C1.2 Institutional and Community Capacity	I1.2.1 Community resiliency	M1.2.1.1 Community capacity index	MO1.2.1.1 Socioeconomic resiliency index
C1.2 Institutional and Community Capacity	I1.2.2 Institutional adequacy	M1.2.2.1 Areas with sustainable management plans, policies or commitments (e.g., acres by ownership and type of agreement)	MO1.2.2.1 Assessment of land tenure policies that restrict sustainabile forest management
		M1.2.2.2 Adequacy of inventories (e.g., index of completeness and currency)	

CRITERION	INDICATOR	MEASURE--RECOMMENDED	MEASURE--OPTIONS
C1.2 Institutional and Community Capacity	I1.2.3 Ownership patterns	M1.2.3.1 Land ownership/tenure (e.g., area by use type)	MO1.2.3.1 Parcel size by ownership type
		M1.2.3.2 Land value by type of use/tenure (e.g., change in per capita value of assessed property; average property value of forest land by commercial/private)	
C1.2 Institutional and Community Capacity	I1.2.4 Government to government relationships	M1.2.4.1 Assessment of government-to-government agreements/plans (e.g., number of by Tribe, State, etc.)	MO1.2.4.1 Government to government interactions/relationships (e.g., number of informal interactions/relationships by Tribe, State, etc.)
C1.3 Social equity	I1.3.1 Environmental justice and civil rights	M1.3.1.1 Civil rights violations (e.g., number or severity by type) M1.3.1.2 Small business/minority set asides (e.g., number, dollar value, extent by program area) M1.3.1.3 Distribution of workforce (e.g., gender, ethnicity, age, etc.) M1.3.1.4 Environmental justice issues (e.g., number of analysis issues identified, remedial actions as result of analysis, number of complaints, etc.)	
C1.3 Social equity	I1.3.2 Disabled access	M1.3.2.1 Accessible facilities (e.g., proportion/number facilities available by activity)	
C1.3 Social equity	I1.3.3 Worker health and safety	M1.3.3.1 Worker safety incidents (e.g., lost time injury frequency rate; number per year) M1.3.3.2 Intensity and extensity of workforce trained (e.g., number of workers or months of training by program/topic area)	MO1.3.3.1 Worker health and safety claims (e.g., number or value of those filed per year)
			MO1.3.3.3 Compliance with inspections (e.g., number of violations or # outstanding violations by severity)
C1.3 Social equity	I1.3.4 Public health and safety	M1.3.4.1 Public safety incidents (e.g., number of incidents by type/severity)	

CRITERION	INDICATOR	MEASURE--RECOMMENDED	MEASURE--OPTIONS
C1.4 Social and cultural values	I1.4.1 Gathering	M1.4.1.1 Participation in harvest for personal use (e.g., number of persons participating in harvest for consumption/cultural purposes)	MO1.4.1.1 Availability of subsistence use programs (e.g., number by type, knowledge of availability)
		M1.4.1.2 Participation in harvest for Native American use (e.g., number of persons participating in harvest for consumption/cultural purposes)	MO1.4.1.2 Availability of Native American subsistence use programs (e.g., number by type; knowledge of availability)
			MO1.4.1.3 Conflicts between Native American use and other activities (e.g., number of by type such as FS policy, commercial harvest, etc.)
C1.4 Social and cultural values	I1.4.2 Aesthetics and Solitude	M1.4.2.1 Scenic quality index (e.g., acres by visual quality objective class, acres needing rehabilitation by visual quality objective class)	
		M1.4.2.2 Availability of places for solitude (e.g., acres of forest buffered from collector or arterial roads, acres of forest not under flight paths, etc.)	
C1.4 Social and cultural values	I1.4.3 Education and research	M1.4.3.1 Interpretive facilities available (e.g., number of by type)	
		M1.4.3.2 Interpretation, education, and research participation (e.g., number of contacts by type)	
			MO1.4.3.3 Interpretation, education, research expenditures (e.g., total expenditures or proportion of total expenditures on educational/interpretive/research materials)
			MO1.4.3.4 Research activities (e.g., number of efforts to promote/enable research)
C1.4 Social and cultural values	I1.4.4 Cultural values and historic features	M1.4.4.1 Protection of cultural and historic sites (e.g., total number, number with minimum buffer protection widths or other protective mechanisms)	MO1.4.4.1 Cultural and historic sites identified (e.g., number of sites that have been evaluated)
		M1.4.4.2 Cultural and historic sites that have been negatively impacted (e.g., number of sites impacted)	MO1.4.4.2 Cultural and historic site monitoring for protection (e.g., number sites monitored annually, archaeological field monitoring days)

CRITERION	INDICATOR	MEASURE--RECOMMENDED	MEASURE--OPTIONS
C1.4 Social and cultural values	I1.4.5 Spiritual values and special places	M1.4.5.1 Areas managed for special places/values (e.g., acres/proportion old growth, deer management, wetland areas, etc.)	
C1.4 Social and cultural values	I1.4.6 Access and use rights	M1.4.6.1 Road access (e.g., miles by road class)	
		M1.4.6.2 Access restrictions (e.g., acres of forest with restricted access by restriction type)	MO1.4.6.2 Access restrictions (e.g., special acts/closure orders; number permits denied due to access concerns; restrictions by inholdings; number of non-access days)
		M1.4.6.3 Special use permits (e.g., number of special use permits by type)	
			MO1.4.6.4 Areas available for recreation (e.g., Scenery Management System by Recreation Opportunity Spectrum)
C1.4 Social and cultural values	I1.4.7 Recreation and tourism	M1.4.7.1 Recreation use (e.g., Recreation Visitor Day by Recreation Opportunity Spectrum)	MO1.4.7.1 Visitors use (e.g., number of visitors)
		M1.4.7.2 Recreation user satisfaction (e.g., visitor survey by activity type)	
			MO1.4.7.3 Recreation supply (e.g., Persons at One Time by Recreation Opportunity Spectrum)
C1.4 Social and cultural values	I1.4.8 Customs and culture	M1.4.8.1 Public satisfaction with management for sense of place (e.g., public survey, interviews, etc.)	
			MO1.4.8.2 Facilities available to support customary and traditional activities (e.g., number of facilities)
			MO1.4.8.3 Services and mechanisms available to support customary and traditional activities (e.g., number of special use permits for recreation events)
			MO1.4.8.4 Conflicts between United States Forest Service and customary users (e.g., number of conflicts)

Principle P2: Maintain Ecological Integrity

CRITERION	INDICATOR	MEASURE--RECOMMENDED	MEASURE--OPTIONS
C2.1 Landscape function	I2.1.1 Disturbance processes	M2.1.1.1 Intensity/extensity/frequency of disturbance processes (e.g., degree of organic matter removal by fire, proportion of landscape disturbed by wind annually, return interval for fire)	
			MO2.1.1.2 Risk assessment of disturbance processes (e.g., area at high risk of mortality due to insects or disease, fire risk condition class)
C2.1 Landscape function	I2.1.2 Hydrologic function	M2.1.2.1 Watershed condition index (e.g., hydrologic condition assessment)	
		M2.1.2.2 Drought/Flood severity measures (e.g., Palmer drought severity index)	MO2.1.2.2 Precipitation measures (e.g., inches of rainfall/ snowfall, snowpack depth)
			MO2.1.2.3 Snow/Ice phenology (e.g., rate of glacier recession, date of lake ice on/off)
C2.1 Landscape function	I2.1.3 Long-term community dynamics	M2.1.3.1 Longevity of current community assemblages (e.g., changes in dominant species based on vegetation history derived from pollen cores, presence of historic soil profiles, fossil evidence of past plant/animal communities)	
C2.2 Landscape structure/composition	I2.2.1 Landscape diversity	M2.2.1.1 Assessment of vegetation community types including permanent conversions (e.g., acres or relative proportion of each type)	
		M2.2.1.2 Horizontal and vertical structural diversity of vegetation (e.g., number of vegetation layers present)	
			MO2.2.1.3 Management guidelines present and utilized by ecological land types
C2.2 Landscape structure/composition	I2.2.2 Landscape patterns	M2.2.2.1 Patch size and patch shape metrics (e.g., mean patch size and edge to interior ratios etc., by forest/non-forest area; by succesional stage; by community type)	MO2.2.2.1 Landscape pattern effect on habitat (e.g., percent of sub-basin with suitable habitat for selected species; HABSCAPES model)

CRITERION	INDICATOR	MEASURE--RECOMMENDED	MEASURE--OPTIONS
		M2.2.2.2 Patch distribution and connectivity (e.g., dispersion index, characterization of random/regular/clumped patches, inter-patch distance, nearest neighbor measurement)	
		M2.2.2.3 Density and distribution of human developed features (e.g., road density, number of road crossings, distance to human developed features, by use class)	
C2.3 Ecosystem function	I2.3.1 Productive capacity	M2.3.1.1 Net primary productivity (e.g., remote sensing measures of site productivity)	MO2.3.1.1 Productive capacity (e.g., estimate based on climate, chlorophyll per unit area, etc.)
		M2.3.1.2 Tree growth rate (e.g., annual increment, basal area growth)	
		M2.3.1.3 Forage condition class assessment	MO2.3.1.3 Forage quantity and quality (e.g., animal unit months, pounds forage produced)
		M2.3.1.4 Animal and fish productivity (e.g., number of individuals or pounds annually, shared measure, in part, with M2.6.1.1)	
C2.3 Ecosystem function	I2.3.2 Functional diversity	M2.3.2.1 Areas impacted by hyper/hypo species abundance (e.g., acres where deer exceed carrying capacity)	
		M2.3.2.2 Diversity within selected guild populations (e.g., number of species, redundancy of species)	
C2.3 Ecosystem function	I2.3.3 Invasive species	M2.3.3.1 Presence of exotic species (e.g., number of exotic plant species)	
		M2.3.3.2 Areas affected by invasive species (e.g., acres invaded, rate of spread)	MO2.3.3.2 Risk assessment of invasive species (e.g., acres at risk)
			MO2.3.3.3 Adequacy of monitoring to detect invasive species
C2.3 Ecosystem function	I2.3.4 Nutrient cycling	M2.3.4.1 Soil organic matter content (e.g., percent organic matter in 'A' horizon of soil)	MO2.3.4.1 Litter accumulation/decay (e.g., pounds per acre, litter extent, 'O' horizon depth, percent cover, percent bare soil)

CRITERION	INDICATOR	MEASURE--RECOMMENDED	MEASURE--OPTIONS
			MO2.3.4.2 Soil macro/micro fauna diversity (e.g., number of species)
	I2.3.5 Carbon sequestration	M2.3.5.1 Soil carbon (e.g., pounds of carbon in soil per acre)	MO2.3.5.1 Soil carbon 'A' horizon (e.g., based on depth of 'A" horizon and percent carbon present) MO2.3.5.1 Soil carbon as determined from CWD (e.g., pounds of CWD by decay class)
		M2.3.5.2 Biomass carbon sink (e.g., timber volume equivalents)	
	I2.3.6 Stream function	M2.3.6.1 Assessment of stream segments in proper functioning condition (e.g., proportion of stream in proper functioning condition)	MO2.3.6.1 Assessment of the quality and extent of riparian vegetation (e.g., stream miles with intact riparian vegetation/ thermal cover) MO2.3.6.1 Presence of stream structural elements (e.g., number and distribution of in stream structural elements such as coarse woody debris and large boulders)
C2.4 Ecosystem structure/composition	I2.4.1 Air, soil and water quality	M2.4.1.1 Air quality attributes (e.g., number of days of non-compliance with standards such as visual quality or ozone level, lichen health index based on coverage of arboreal lichens, direct measures of pollutants per volume of air)	
		M2.4.1.2 Index of biotic integrity for aquatic systems (e.g., index biotic integrity by stream segment or watershed)	MO2.4.1.2 Water quality attributes (e.g., number of water bodies that exceed water quality standards such as temperature, fecal coliform, 303(d) list, EPA "impaired list", turbidity, etc.; number of spills per year, number of fish mercury advisories; PH measures including PH of precipitation)
		M2.4.1.3 Soil quality attributes (e.g., number of departures from BMP for soil quality, level of pollutants per unit volume of soil, bulk density measurement; soil nutrient analysis)	

CRITERION	INDICATOR	MEASURE--RECOMMENDED	MEASURE--OPTIONS
C2.4 Ecosystem structure/composition	I2.4.2 Ecological legacies	M2.4.2.1 Assessment of Coarse Woody Debris and Snags (e.g., volume of CWD or number of snags per acre by decay class, by size class, by vegetation community type)	
		M2.4.2.2 Assessment of Snags (e.g., number of snags per acre by decay class, by size class, by vegetation community type)	
			MO2.4.2.3 Assessment of other ecological legacies (e.g., number of, or acres of features such as raptor nests, boulder fields, wallows, ant hills, beaver dams, legacy trees, etc).
C2.4 Ecosystem structure/composition	I2.4.3 Special habitats	M2.4.3.1 Assessment of areas of special interest (e.g., reserve acres, wilderness acres, winter deer yards, etc., by condition class and protection status)	
			MO2.4.3.2 Guidelines are in place for the management of special interest areas
C2.4 Ecosystem structure/composition	I2.4.4 Species richness	M2.4.4.1 Assessment of species richness (e.g., number of species present within target species group such as birds or by species guild such as cavity nesters, by vegetation community type, management type)	
		M2.4.4.2 Assessment of species of concern (e.g., number of extirpated or endangered species)	
C2.5 Population function	I2.5.1 Population viability	M2.5.1.1 Population viability analysis of selected species (e.g., index based on measures of population dynamics, population genetics, environmental variation, metapopulation structure, and habitat suitability, etc.)	MO2.5.1.1 Habitat suitability analysis (e.g., acres of suitable habitat for selected species based on habitat models)
C2.6 Population structure/composition	I2.6.1 Populations of indigenous species	M2.6.1.1 Populations of selected species (e.g., population size, density, age class, sex ratio)	MO2.6.1.1 Habitat suitability analysis (e.g., acres of suitable habitat for selected species based on habitat models)
		M2.6.1.2 Assessment of species' metapopulations (e.g., size, number and distribution of metapopulations)	

CRITERION	INDICATOR	MEASURE--RECOMMENDED	MEASURE--OPTIONS
			MO2.6.1.3 Number of selected species with completed conservation assessment and recovery plans
C2.7 Organism function	I2.7.1 Genetic mixing	M2.7.1.1 Assessment of the existence and use of native and non-native stock rules	
C2.7 Organism function	I2.7.2 Genetic migration	M2.7.2.1 Assessment of migration barriers (e.g., number water control structures per river mile) M2.7.2.2 Assessment of the persistence of species on the edge of their range (e.g., population size of species on edge of range)	
C2.7 Organism function	I2.7.3 Genetic selection	M2.7.3.1 Assessment of the alteration of native species gene pools (e.g., percent of area where selected species do not reach sexual maturity prior to harvesting, acres of vegetation communities where management actions or selection pressures lead to unnatural selection pressures)	
C2.8 Organism structure/composition	I2.8.1 Genetic diversity	M2.8.1.1 Assessment of areas converted to non-native gene pool (e.g., acres converted, proportion of landscape converted)	
		M2.8.1.2 Allele and genotype frequencies for selected species (e.g., difference from expected natural heterozygocity)	MO2.8.1.2 Assessment of minimum viable populations (e.g., population size of species with limited gene pools) MO2.8.1.3 Presence of adequate genetic reserves/gene banks (e.g., acres)

Principle P3: Economic Well-being

CRITERION	INDICATOR	MEASURE--RECOMMENDED	MEASURE--OPTIONS
C3.1 Capital and wealth	I3.1.1 Natural capital - forests	M3.1.1.1 Compare productive forest to total forest (e.g., proportion by ownership, forest type, species, etc.) M3.1.1.2 Amount of productive forest (e.g., timber volume by ownership, forest type, species, etc.) M3.1.1.3 Value of productive forest (e.g., $ value by ownership, forest type, species, etc.)	MO3.1.1.1 Total amount of forest (e.g., acres)
C3.1 Capital and wealth	I3.1.2 Natural capital - recreation	M3.1.2.1 Areas available for recreation (e.g., Scenery Management System by Recreation Opportunity Spectrum) M3.1.2.2 Areas of wilderness	
C3.1 Capital and wealth	I3.1.3 Natural capital - wildlife/fish	M3.1.3.1 Wildlife populations	MO2.6.1.1 Assessment of suitable habitat for selected species (e.g., habitat suitability models) MO3.1.3.2 Assessment of fish bearing streams (e.g., stream miles)
C3.1 Capital and wealth	I3.1.4 Natural capital - range	M3.1.4.1 Amount of productive range (e.g., acres by forage condition class)	
C3.1 Capital and wealth	I3.1.5 Other natural capital	M3.1.5.1 Special management areas (e.g., acres of research natural areas, special interest areas, wild scenic rivers, etc.) M3.1.5.2 Water resources (e.g., volume available)	
		M3.1.5.3 Special forest products (e.g., lbs of edible mushrooms)	MO3.1.5.3 Value of special forest products (e.g., $ value of annual edible mushroom harvest)
		M3.1.5.4 Areas of oil, gas and mineral potential (e.g., assessment of proven reserves)	
			MO 3.1.5.5 Natural capital ownership (e.g., proportion public to private forest ownership)

CRITERION	INDICATOR	MEASURE--RECOMMENDED	MEASURE--OPTIONS
C3.1 Capital and wealth	I3.1.6 Built infrastructure - roads and trails	M3.1.6.1 Roads and trails (e.g., miles of roads/trails by use type and capacity)	
		M3.1.6.2 Condition of roads and trails (e.g., miles to standard)	MO3.1.6.2 Asset value of roads and trails (e.g., $ value of roads/trails by use type)
			MO3.1.6.3 Roads and trails maintenance cost
			MO3.1.6.4 Roads and trails maintenance backlog
C3.1 Capital and wealth	I3.1.7 Built infrastructure - recreation facilities	M3.1.7.1 Recreation facilities (e.g., number of recreation facilities by type)	
		M3.1.7.2 Capacity of recreation facilities	
		M3.1.7.3 Condition of recreation facilities	MO3.1.7.3 Recreation facilities maintenance cost
			MO3.1.7.4 Recreation facilities maintenance backlog
			MO3.1.7.5 Asset value of recreation facilities
C3.1 Capital and wealth	I3.1.8 Built infrastructure - other facilities	M3.1.8.1 Other facilities (e.g., number of by type)	
		M3.1.8.2 Condition of other facilities	MO3.1.8.2 Other facilities maintenance cost
			MO3.1.8.3 Asset value of other facilities
			MO3.1.8.4 Other facilities maintenance backlog
C3.1 Capital and wealth	I3.1.9 Human capital	M3.1.9.1 Assessment of labor pool (e.g., size/distribution by gender, ethnicity, age etc.)	
C3.2 Flows of products and services	I3.2.1 Production of marketed goods and services	M3.2.1.1 Timber harvested (e.g., million board feet by type)	MO3.2.1.1 Value of timber produced
		M3.2.1.2 Recreation use (e.g., recreation visitor day by recreation opportunity spectrum)	MO3.2.1.2 Value of recreation produced
		M3.2.1.3 Wildlife harvested	MO3.2.1.3 Value of wildlife harvested
		M3.2.1.4 Fish harvested	MO3.2.1.4 Value of fish harvested
		M3.2.1.5 Animal unit month used	MO3.2.1.5 Value of animal unit month produced
		M3.2.1.6 Oil, gas and minerals produced (e.g., volume by type/grade)	MO3.2.1.6 Value of minerals produced
		M3.2.1.7 Electrical power generated (e.g., kw hours)	MO3.2.1.7 Value of energy produced

CRITERION	INDICATOR	MEASURE--RECOMMENDED	MEASURE--OPTIONS
		M3.2.1.8 Water withdrawals (e.g., volume)	MO3.2.1.8 Value of water withdrawals
		M3.2.1.9 Contribution to Gross Domestic Product/Gross Regional Domestic Product	
C3.2 Flows of products and services	I3.2.2 Production of non-marketed goods and services	M3.2.2.1 Special forest products harvested (e.g., lbs of mushrooms)	MO3.2.2.1 number of special forest product permits issued
		M3.2.2.2 Wilderness/backcountry permits (e.g., number of permits issued per year)	
		M3.2.2.3 Special use permits (e.g., number of permits issued per year)	
C3.3 Trade and distributional equity	I3.3.1 Trade balance	M3.3.1.1 Value of imports to exports	MO3.3.1.1 Timber imports to exports (e.g., volume of timber imports/exports)
C3.3 Trade and distributional equity	I3.3.2 Workforce diversity	M3.3.2.1 Distribution of workforce (e.g., gender, ethnicity, age)	
		M3.3.2.3 Assessment of contracts to minority-owned or small businesses (e.g., proportion/value of contracts)	
			MO3.3.2.4 Average commuting time
C3.3 Trade and distributional equity	I3.3.3 Income	M3.3.3.1 Size distribution of income (e.g., percent by tenure type)	
		M3.3.3.2 Technical distribution of income (e.g., by factor type)	MO3.3.3.2 Technical distribution of employment
		M3.3.3.3 National Forest System total program expenditures (e.g., $ annual by program)	MO 3.3.3.3 National Forest System operating budget
			MO 3.3.3.4 National Forest System generated revenues (e.g., receipts)
C3.3 Trade and distributional equity	I3.3.4 Equity	M3.3.4.1 Distribution of rent: timber (percent rent by recipient)	
		M3.3.4.2 Distribution of rent: recreation (percent rent by recipient)	
		M3.3.4.3 Distribution of rent: range (percent rent by recipient)	
		M3.3.4.4 Distribution of rent: stewardship/protection (percent rent by recipient)	
			MO3.3.4.5 Distribution of payments in lieu of taxes

CRITERION	INDICATOR	MEASURE--RECOMMENDED	MEASURE--OPTIONS
			MO3.3.4.6 25% Fund MO3.3.4.7 Other FS distributions (e.g., range betterment fund) MO3.3.4.8 Other non-FS distributions (e.g., coal and gas royalties)
C3.4 Efficiency	I3.4.1 Net Rent	M3.4.1.1 Net rent: timber (income-expenditures) M3.4.1.2 Net rent: recreation (income-expenditures) M3.4.1.3 Net rent: range (income-expenditures) M3.4.1.4 Net rent: stewardship/protection (income-expenditures)	

APPENDIX 11.

TOOLS TO ASSIST IN CONCEPTUAL MODEL DEVELOPMENT

Slocombe (2001) suggests the use of graphical, systems-oriented methods such as network diagrams that allow network analysis. Object-oriented tools that allow multiple relationships with the same element are particularly useful while hypertext type methods allow users to follow links in nonlinear fashions "depending on the questions of interest and the connections that make sense to them" (Slocombe 2001). Tools that allow the user to build a conceptual model and then convert it for analytical purposes are particularly helpful but the limitation is typically associated with finding a tool that can transfer the 'richness' of the connections built in a conceptual model into an analytical tool.

Constructing conceptual models is a relatively simple task. Most sources recommend that the team start with any concept or dimension of a system and then work outwards building in connections to related elements. Conceptual modeling can easily be performed without the use of any technical tools however there are a number of possible tools that can be used to assist in the function.

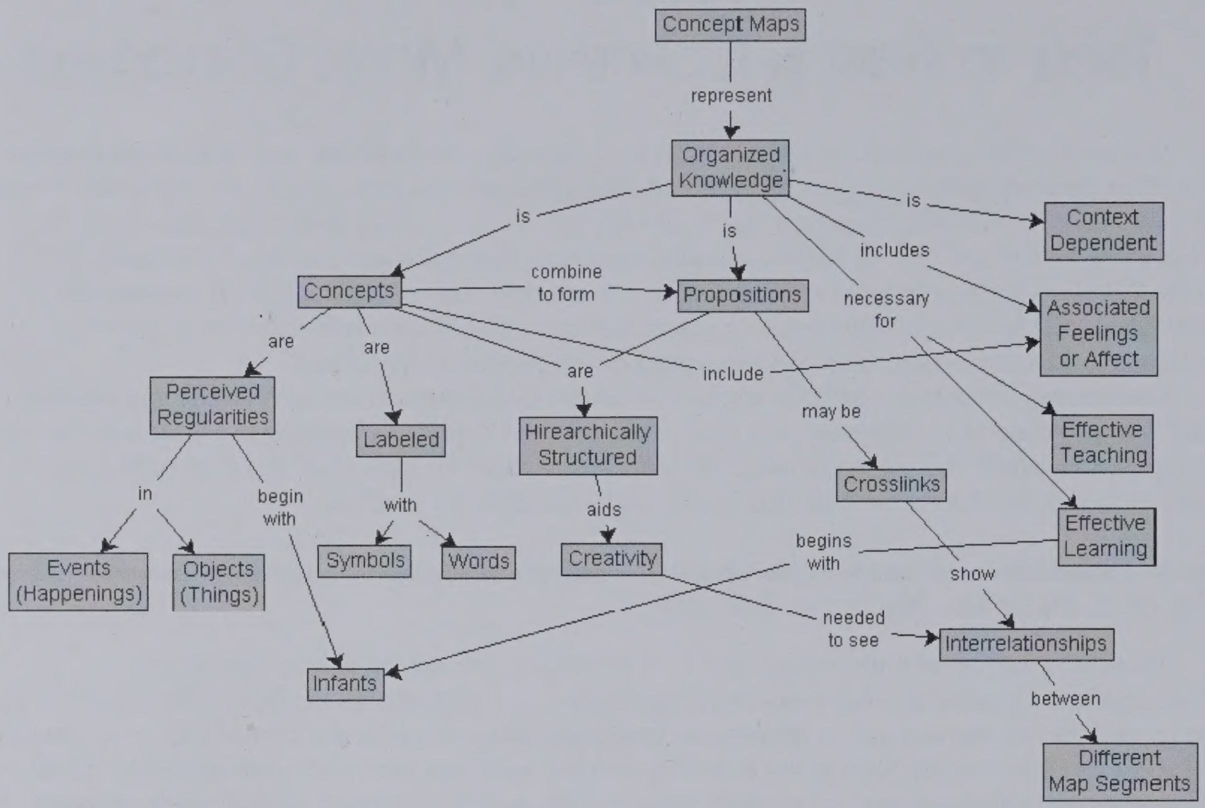
USE OF CONCEPTUAL MODELING SOFTWARE

There are a variety of different approaches to developing conceptual models from graphic representations on paper to conceptual modeling software (see sidebars). In the LUCID Project, all of the teams used NetWeaver as a tool to develop the broad conceptual model of the suite of C&I. Key features of the software (discussed in detail in the following chapter) including its expert-based approach, spatial dimensions and object-oriented nature made it particularly useful for constructing a conceptual model. The resulting model could be displayed component by component in detail or as an overall network of dependencies and the user could trace and easily identify related components. NetWeaver was selected as the conceptual modeling tool because of these characteristics but also because the same software could be used to analyze the results of sustainability monitoring when reference values and data were added. The efficiency of using one tool for both purposes seemed to make it a wise choice. Our experience, however, was that although the software was relatively easy to learn and manipulate the use of a computer-based tool seemed to act as a bit of a barrier for entry and engagement in the development of the model. This effect might be even more exaggerated within a more collaborative process. Consequently even though it would have required an extra step of translating a more informal conceptual model into the analytical software of NetWeaver LUCID participants may have benefited more from the conceptual modeling process if a less technical approach had been used initial. The choice of the tool should be reconsidered in each situation based on the timing, the working style and composition of the team and the ultimate use of the conceptual model.

EXAMPLE CONCEPTUAL MODELING TOOLS

C-Map (Version 2.7.3): Conceptual Map Tools is a shareware program developed by the University of Western Florida to help organize knowledge basis into sets of objects and connections. The conceptual map created by the developers provides an overview of the key aspects of this conceptual mapping tool in an example concept map (www.cmap.coginst.uwf.edu). C-Map images are schematic in nature only and while they can be saved in a number of different formats do not have analytical capabilities. Directionality is indicated by the use of arrows. C-Map was used in as a conceptual modeling tool in the extension to the LUCID Project ongoing in Chihuahua, Mexico.

Concept Map of the C-Map Tool


Concept Maps
represent
Organized Knowledge
is
is
is
Context Dependent
includes
Concepts
combine to form
Propositions
necessary for
Associated Feelings or Affect
are
are
are
include
may be
Perceived Regularities
Labeled
Hirearchically Structured
Effective Teaching
Crosslinks
in
begin with
with
aids
Effective Learning
begins with
show
Events (Happenings)
Objects (Things)
Symbols
Words
Creativity
needed to see
Interrelationships
Infants
between
Different Map Segments

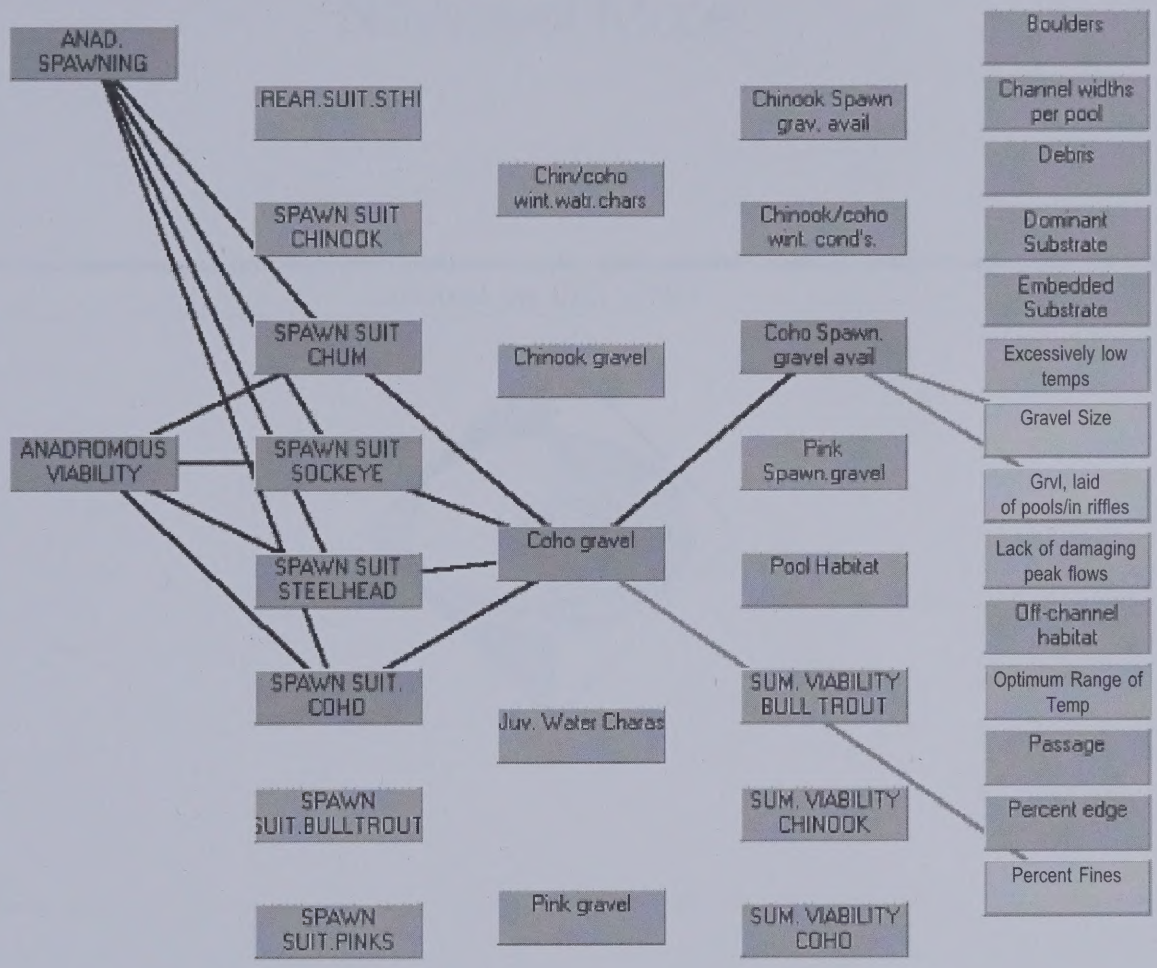
MICROSOFT OFFICE VISIO

Visio is a MS application can be used to quickly assemble diagrams using a drag and drop function of common shapes. Visio is object oriented such that properties stay with their shapes and the items and arrangements can be easily manipulated. Visio diagrams can be easily uploaded to serve as Web pages with hyperlink properties and a range of other navigational tools. Visio can work with existing database files (e.g., Excel) for a limited number of applications such as the creation of Gantt charts, however it is primarily a conceptual modeling tool and not an analytical modeling tool. Direction can be indicated through arrows of different weights and sizes. Visio was used in the LUCID Project to produce graphics of the final suite of LUCID C&I from principles through measures (Chapter 11).

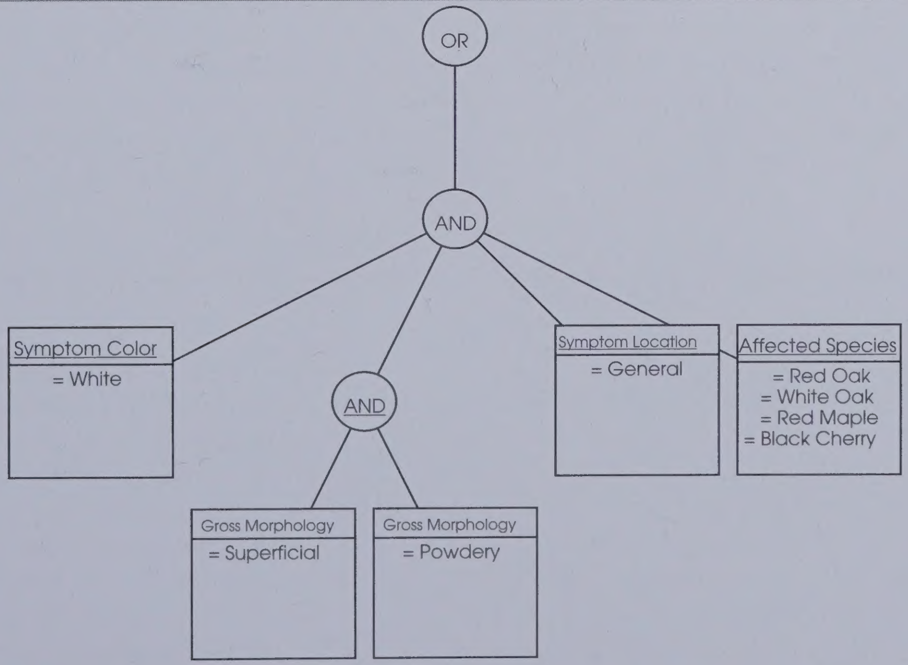
NETWEAVER

NetWeaver is an expert-knowledge tool that is object oriented in nature. As a conceptual modeling tool it allows the user to link objects in a series of nodes and networks joined by different standard logical operators (e.g., AND, OR etc.,). NetWeaver is hierarchical in nature such that objects are ordered sequentially but it is unidirectional in nature. Where an object is used more than once in the network, however, navigational tools guide the user to both locations. NetWeaver models can be displayed visually as an overall dependency network or hierarchically network by. The results can be saved in an html format for web documentation. Print and display abilities are currently relatively limited. A key feature of NetWeaver is that the program is both a conceptual and analytical modeling tool. With the addition of reference values and data the model results can be analyzed either graphically or spatially (with the GeoNetWeaver program extension).

DEPENDENCY NETWORK OVERVIEW IN NETWEAVER


ANAD. SPAWNING
.REAR.SUIT.STHI
SPAWN SUIT CHINOOK
SPAWN SUIT CHUM
ANADROMOUS VIABILITY
SPAWN SUIT SOCKEYE
SPAWN SUIT STEELHEAD
SPAWN SUIT. COHO
SPAWN SUIT.BULLTROUT
SPAWN SUIT.PINKS
Chin/coho wint.watr.chars
Chinook gravel
Coho gravel
Juv. Water Charas
Pink gravel
Chinook Spawn grav. avail
Chinook/coho wint. cond's.
Coho Spawn. gravel avail
Pink Spawn.gravel
Pool Habitat
SUM. VIABILITY BULL TROUT
SUM. VIABILITY CHINOOK
SUM. VIABILITY COHO
Boulders
Channel widths per pool
Debris
Dominant Substrate
Embedded Substrate
Excessively low temps
Gravel Size
Grvl, laid of pools/in riffles
Lack of damaging peak flows
Off-channel habitat
Optimum Range of Temp
Passage
Percent edge
Percent Fines

NETWEAVER NETWORK DIAGRAM


OR
AND
Symptom Color
= White
AND
Gross Morphology
= Superficial
Gross Morphology
= Powdery
Symptom Location
= General
Affected Species
= Red Oak
= White Oak
= Red Maple
= Black Cherry

APPENDIX 12.
NETWEAVER MODEL

LOCATED ON CD ONLY!

APPENDIX 13.
REPORTING AND PRESENTATION IDEAS

Although selecting the criteria and indicators, setting reference standards and populating the analytical models and tools with data are critical and time consuming stages of a sustainability monitoring program it is in the analysis and presentation stage where meaning and value is gained from the monitoring program. A common critique of monitoring programs is that they often appear to have little value to the users however much of this may have less to do with the content of the monitoring program and more to do with how the results are reported and presented.

Reports on sustainability assessments from monitoring programs are varied. In some cases the reports are stand-alone such as 'state of the system' reports (e.g., the FAO's 2001 State of the Worlds' Forests) or specific reports on monitoring progress on a suite of indicators (e.g., the United States First Approximation Report). Some reports are summary in nature (where others are more interpretive trying to probe the relationships between elements. The kind of report, the presentation techniques (narrative vs. graphic displays) and the distribution mechanisms (e.g., web-based or paper-based) will vary according to the intended audiences.

As with the overall analysis process, forest teams noted that their reporting process was very preliminary in nature. All mentioned that given the test parameters and time frame they did not have adequate time to do a full analysis and to report all of the detail that they wanted. However the preliminary pursuits of possible reporting and presentation ideas surfaced a number of interesting approaches and important discussions.

PURPOSE AND AUDIENCE

Clarifying the purpose and the audience was a critical discussion point for the forest teams. During the LUCID Project, given the pilot nature of the test, limited guidance was given to the forest teams regarding the potential audiences and uses for the report. LUCID participants noted that clarifying the audiences and purposes of the report would be absolutely critical in the future and that in all likelihood a variety of different reporting and presentation techniques would be needed.

STAND-ALONE VERSUS INTEGRATED REPORT

As a pilot project the results of the preliminary sustainability monitoring effort were produced as stand-alone products. LUCID participants discussed the merits of the producing stand-alone reports versus reporting on sustainability progress in more integrated formats. Most noted that there were merits in occasional (e.g., perhaps on a 3- to 5-year time cycle) production of stand-alone reports on the state of the system in particular for sharing with broader public audiences. However, LUCID participants noted that for the results of sustainability monitoring to have the most value for management decisionmaking reporting should be more integrated.

CONSISTENCY VS. FLEXIBILITY

The issues of consistency and flexibility were central to discussions regarding reporting. LUCID participants and forest supervisors noted the value in a consistent approach to reporting to facilitate both Forest Service and the public's review and understanding of progress towards sustainability. All noted, however, that there needed to also be a balance between a consistent approach (perhaps with a list of commonly defined elements that might be included) and the flexibility to customize reporting to tell the unique stories of the forest in ways that match the audiences need.

RANGE OF PRESENTATION TOOLS

Forest teams explored a range of different presentation tools from narrative summaries and interpretation of results to mapped presentations and graphic summaries. Forest teams did not pursue more summary report card approaches such as those used in the Oregon Benchmark report although they did indicate interest in examining the possibility of using these report card type approaches.

The graphic nature of NetWeaver allowed for the potential for producing graphics directly from the tool. Although in most cases the values used for analysis and reporting came from assessing the data against standards within the NetWeaver process those forest teams who focused on presentation and reporting techniques recognized the need to use other tools for presenting the results. The map extension, GeoNetWeaver was noted as a particularly valuable way of presenting results. The utility to import and export results from NetWeaver and manipulate them with other graphic design programs is recommended as a way to improve the functionality of this tool.

USEFUL REPORT COMPONENTS

The forest team reports ranged in scale and scope but shared some common elements. Most of the reports presented a view of the baseline conditions across the suite of C&I they monitored and most talked in detail about the nature and type of missing data and the extent to which it affected the results. In addition to the baseline presentation, three of the forests pursued the analysis and presentation of specific management issues and a few of the forests did a comparison between the FMU scale C&I and overlap with monitoring initiatives.

Other components that were provided in some reports that were useful for setting the context for the reader and to understand the results included:

- A table of contents;
- A management summary (executive summary) that summarized the key messages including the assumptions and limitations;
- A brief background and description of the value of sustainability monitoring and the history behind the approach;
- A brief overview of the forest;
- A description of the bounds of the study area (e.g., the Allegheny unglaciated plateau) and why that area was selected;
- A description of the bounds of the analysis area if it was different from the study area definition (e.g., due to lack of data availability during the pilot test the forest boundary was used for all analysis);
- Limitations and assumptions that the reader should be aware of (e.g., missing data, standards, scale issues);
- Narrative presentation of results supplemented with graphic presentation support (e.g., maps, charts etc);
- Technical details (e.g., details on standards or NetWeaver calculated values) in appendixes or summarized in tables;
- Text and tables (and other graphics) that are independent from one-another (e.g., material in tables/figures should have detailed captions such that the reader understands how to interpret the results and what assumptions and limitations are associated with them. Similarly, material in tables/figures should be summarized in the text);
- Thorough discussion of management implications, options or recommendations;
- Suggestions for next steps in the sustainability assessment or monitoring process.

Comments on Consistency and Flexibility Implications for Reporting from LUCID Participants

- Nationally there is a momentum to work towards standardized format, which will help the public to have an easier time reading.
- Give some general guidelines, but allow for the forest to have their own style (allows creativity of people to take their own flow).
- Give sections but then allow those to be filled out as the forests want.
- A menu of options with examples would be helpful.

APPENDIX 14.
TECHNICAL ISSUES IN WEIGHTING

Common conceptual models of sustainability convey each component or principle (ecological, social, and economic) within an overlapping set of Venn-diagrams or discuss sustainability as a three-legged stool (Figure 14-a). Each leg or circle has equal value and without one the stool will collapse. Alternative conceptual models suggest that sustainability is a set of nested circles with the ecological pre-eminent, and the social, and then economic subsets of these (Figure 14-b). In this model, the ecological principle has more weight than the other two principles.

In its broadest sense the intrinsic weight implied by rigorous application of the C&I hierarchy is that each element, for example an indicator, has the same weight unless a conscious decision is made to adjust these weights. This 'equal weight' assumption is not perfectly straightforward, however. In reality the evaluation is that the item (e.g., an indicator) one hierarchical level above (e.g., the measures) has an equal weight with all other indicators when indicators are evaluated against each other. Because each criterion has a different number of indicators, and each indicator has a different number of measures (and so on), the relative contribution of an indicator where the criterion has five indicators is less than the contribution of an indicator where the criterion has only two indicators.

The first question to answer is whether each element within a hierarchical level is of equal importance. The change in hierarchical level may result in a different conclusion about the utility of weighting. If a common systems framework (defined by principles and criteria) is adopted based on an identification of fundamental system properties then the decision may be that the criteria are also of equal importance consequently weighting at the criterion level would not be used. The same decisions must be made at the hierarchical levels of indicator and then measure (and data elements if they represent a further hierarchical level). Are indicators of equal importance or are some more important than others? The determination of relative importance may be more likely to be variable at lower levels of the C&I hierarchy because there may be greater confidence in the validity of certain measures and associated data elements or a stronger more predictive relationship between certain measures and the indicator.

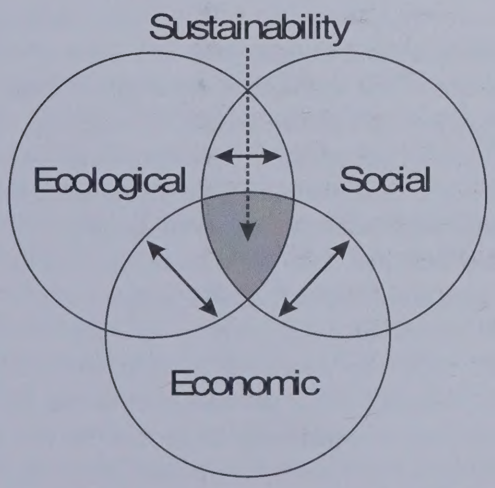


Figure 14-a. Standard Representation of Sustainability as Occurring as a Result of the Meeting of Three Equally Weighted Systems

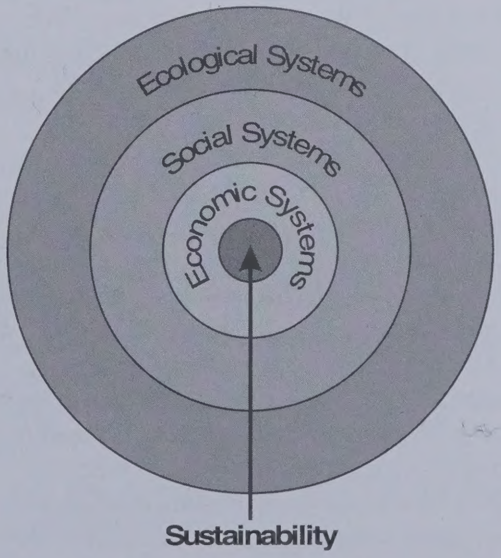


Figure 14-b. Alternative Representation of Sustainability Suggesting that Economic and Social Systems are Nested within Ecological Systems

Once the determination has been made regarding the relative importance of each element within a hierarchical level (e.g., each indicator) then the next critical question is what is the intended implication of how all elements at one hierarchical level, (e.g., the indicator) contribute to the next hierarchical level (e.g., the criterion). This question combines the use of the weighting tool with the aggregating algorithm. If the value of the criterion is the result of a 'sum' algorithm then the value for each indicator when its associated measures are compared to the reference values are simply added. If indicator weights have been applied then those indicators carry more relative value in the sum argument. The mathematical implications of weighting are most transparent with the 'sum' algorithm. However, under the simple 'sum' algorithm, the more indicators there are, the greater the value of the criterion even before weights are applied. The 'sum' algorithm does not work particularly well consequently if different criterion for example might require greater or fewer numbers of indicators to appropriately measure it. An *a priori* decision to have an equal number of elements at each hierarchical level (including the spatial levels) would be required before the 'sum' algorithm would be viable.

To get around the inherent bias of greater or fewer numbers of elements within a hierarchical level an averaging algorithm ('UNION' in NetWeaver terminology) may be selected that calculates the value of the criterion (for example) as an average of the values for the associated indicators. If weighting has been applied to the indicators then the algorithm is a weighted average function. Like the 'sum' algorithm previously mentioned, the relative value of any indicator within a 'union' algorithm is offset by the relative value of others. That is, a certain indicator may rank very poorly when compared to a reference value but this may be masked when the criterion average is examined.

Alternatively a fuzzy math aggregation algorithm ('AND' in NetWeaver parlance) may be selected. The fuzzy math algorithm is based on the premise that the proposition, e.g., a criterion, depends on each of the indicators meeting their conditions to some degree. In this scenario the inability of an indicator to meet its reference value at all cannot be offset by other indicators. Consequently each indicator is of critical importance. The fuzzy math algorithm is conservatively weighted such that indicators with more negative values have more influence on the value of the criterion than indicators with more positive values. The fuzzy math algorithm is calculated based on the values within the achievement scale of –1 to +1. Combining weighting with the fuzzy math algorithm is much more complicated. For example, a weight of two given to one indicator compared to another will not mean that indicator necessarily carries two times the value but rather weight will be combined with the fuzzy math argument. A weight of two on an indicator with a value close to –1 will in actuality result in a contribution much greater than two times the value. A weight of two on an indicator with a value close to +1 may not amount to two times the value if the other indicators in the algorithm have values closer to –1. The interaction of weighting and the fuzzy math aggregation algorithm is straightforward theoretically but in practical use it is very complicated. Although the intent may be to use weighting as a tool in an *a priori* manner to imply the relative importance of a given element relative to others in combination with a fuzzy math algorithm the tool may not perform as intended.

Although weighting can appear to be a straightforward process the mathematical implications challenges weighting can further complicate the selected aggregation algorithm. Consequently the decision to weight must be done with full knowledge of the mathematical implications (see Reynolds 2001 for further discussion of these points). Clearly the intrinsic weighting issue is an important one to be cognizant of and to evaluate the impact on any aggregation algorithm. The use of weighting, and the choice of aggregation algorithms may vary by hierarchical level. Although indicators were used in each of the examples above for commonality the user may decide to use a combination. For example, more conventional algorithms (e.g., 'SUM' or 'AVERAGE') may be used in combination with weighting at the lower levels of a C&I hierarchy if the determination is that not all elements are of equal importance and that not all conditions need necessarily be met. At the upper levels of the C&I hierarchy (e.g., indicators, criterion, principles) if the intent is that poor achievement on one component cannot be offset by others and that each element is of equal important then a fuzzy math algorithm without weighting might be selected.

The technical tool used to assist in analysis should allow the user a means of evaluating the relative weight issue and should clearly document and preferably visually display the application of weighting. Possible solutions to unequal relative inherent weights are: 1) evaluate the implications of relative weights and report the effect and possible implications in the analysis so that the reader can make a decision about the importance of the issue; 2) conduct an analysis only with items at the same level (e.g., all indicators) based on the assumption that each has equal importance; 3) use purposeful weighting to adjust the unequal inherent weight distributions either so that each item does have the same weight or that certain items have more or less weight; or 4) build the hierarchical model with an *a priori* decision rule that each equivalent component must have exactly the same number of elements (including spatial units) with exactly the same importance (This is possible but seems highly unlikely as any suite of C&I that we have evaluated recognizes that some phenomena are more difficult or complex to monitor than others.).

WEIGHTING AND NETWEAVER

Intrinsic Weighting

During the LUCID test we were interested in exploring the implications and options for weighting under these different scenarios. With the analytical approach and technical tool we used for the analysis function we were able to look at the actual contribution or importance of individual elements (e.g., data elements, indicators, criterion etc) and assess whether the hierarchical structure issues and the effect of an unequal distribution of elements within hierarchical layers had a significant effect.

Our conclusion during the LUCID forest tests was that given the large number of total elements in the forest teams suites of C&I, any one element had such a relatively small contribution to the total that while it was important to acknowledge that there was a difference in relative contribution is was deemed negligible. Since most analysis was conducted within the same hierarchical level (e.g., all indicators together) and since we assumed that each and every element that was included was a critical element of equal importance we did not attempt to develop a hierarchical model with the exact number of elements at each hierarchical level. If the suite of C&I to be analyzed were much smaller then this unequal distribution of relative weights would be more important.

Purposeful Weighting

During the LUCID test project forest teams were encouraged not to use the weighting function. This was particularly the case since the forest teams used the fuzzy math algorithm (the ‘and’ algorithm) almost exclusively throughout the hierarchy. The combination of the fuzzy math and weighting algorithm added a level of complexity and subjectivity that we were not prepared to address during the test process.

Upon completion of the selection of the monitoring elements and the initial analysis a number of LUCID forest teams concluded that not all of the elements that they included in their lists of C&I necessarily had equal value and that they thought that weighting should be a viable option. This was particularly true at the lower levels of the C&I hierarchy (e.g., measures and data elements). One of several measures for a select indicator may be identified as the most important measure and others may have less important. Enabling condition or management process measures were often viewed as important but perhaps not as important as other measures. Similarly where forest teams had less confidence in the accuracy or reliability of a certain measure or its associated data or reference value, they often indicated that they felt it was important but perhaps less important than other measures. This was frequently the case when a proxy measure was used.

The LUCID forest teams expressed the desire to implement purposeful weighting most frequently in situations where the following occured:

- There was a desire to convey the importance of different components;
- There was a great deal of uncertainty associated with the measure, the data or the

reference value (e.g., professional judgment or proxy measure use);

- Discrete (typically categorical 'yes/no') reference values were combined with fuzzy reference values;
- There was an undesirable and unequal intrinsic weight phenomena that had a significant effect on the outcome (most typically in smaller analysis processes); or
- Where the item is one the analysis is more sensitive to.

When the LUCID Project was undertaken the original core set of C&I were developed with a set of base assumptions that all items at the same hierarchical level (e.g., all criteria; all indicators etc.,) had equal value and were critical elements of the systems that must achieve at least to some degree the reference values associated with them. For example, no one of the three principles (ecological, social, or economic) was judged to be pre-eminent or of any more importance than the other two. This assumption served as a basis for how the original core set of C&I were developed consequently the examples and guidance for conceptual and analytical model construction worked within the fuzzy math logic of Netweaver. In addition, most dependency networks tended to be joined with 'and' nodes although 'or' nodes were certainly an option. The use of the fuzzy math or 'and' node in NetWeaver was precautionary or conservative in nature such that as results were aggregated up the C&I hierarchy any element that did not meet its reference value even slightly, a –1 value, would have a cascading effect on adjoining components. If 'and' nodes were used to join elements at each level of the hierarchy it was quite feasible and common during that complete non-achievement of a reference value (a –1 value) at the measure level of the C&I hierarchy would have a cascading upward affect resulting in –1 values to the top of the hierarchy.

As the forest teams began their testing process, however, they began to challenge the original assumptions that each item at a hierarchical level had equal value and that the conditions for each must at least be partially met. The key questions that resulted were the following:

- Within a systems context are all elements (e.g., criterion) preconditions for sustainability?
- Are all elements equal to one another?
- Must the conditions for each element be met at least partially?
- Is a precautionary or conservative approach useful and if so when?

As a result of the forest teams concerns and desires, the core team examined and compared various optional algorithms and the interrelated issue of weighting. Clearly if the aggregation algorithm was changed from a fuzzy algorithm to an averaging algorithm then weighting was more straightforward (this approach results in the same algorithm used in CIFOR MCDM Mendoza et al. n.d.). After a review of the initial project assumptions—and based on a comparative analysis of the different approaches—the core team recommends the following responses to the above questions:

1. The systems framework is based on the premise that the criteria represent fundamental system components and processes each of which is critical for sustainability. Additionally a conservative, precautionary approach seems most applicable consequently at principle and criterion levels weighting is not recommended and the fuzzy math ('and') aggregating algorithm seems most appropriate;

2. The selection of the indicators is premised on a 'critical' indicators approach that attempts to get at a parsimonious set of the most important indicators. Consequently weighting is not recommended. Similarly, the fuzzy math aggregation algorithm seems most applicable.

3. At the lower levels of the hierarchy (data elements and measures) the comparison against the reference value should result in a full range of possible assessments from –1 to +1. The interdisciplinary team should evaluate *a priori* whether the failure for an element to meet the reference value even partially (a –1 value) a) can be offset by other elements in which case a 'union' or 'sum' algorithm should be used or b) whether each element is of critical importance and the conditions for it must be met at least partially in which case the fuzzy math 'and' algorithm is appropriate. The choice of the appropriate algorithm should be made on a case by case basis and is dependent on the types of elements (e.g., measures), the nature of the data and an assessment of the importance of each item.
4. Weighting may be a very desirable option at the lower levels of the hierarchy (measures and data elements) but should be used cautiously and the mathematical implications modeled if the aggregating algorithm is the fuzzy logic 'and' node.
5. A consistent approach should be used from forest to forest in determining the appropriate use of weighting and the aggregating algorithms at each hierarchical level.

Methods of Determining Weights

If weighting is implemented weighting values can be determined through statistical analysis or through expert/professional judgments. Causal models frequently use statistical analysis (e.g., multivariate factor analysis) to examine and identify the relative contribution of components in a predictive model. These factor scores can then be applied as weights. Because causal models are generally lacking for most components within sustainability monitoring programs expert panels or professional judgments are frequently used to determine weights. For example in identifying critical factors for habitat suitability models for grizzly bears researchers conducted a multi-stage (e.g., Delphi process) rating of a series of indicators to identify the relative value (using Bayesian probability approaches) of each indicator.

APPENDIX 15.

MONTREAL PROCESS CRITERIA AND INDICATORS

CRITERION 1: Conservation of biological diversity

Criteria Level Summary

Indicator 1: (MP-1.1.a) Extent of area by forest type relative to total forest area.

Indicator 2: (MP-1.1.b) Extent of area by forest type and by age class or successional stage.

Indicator 3: (MP-1.1.c) Extent of area by forest type in protected area categories as identified by IUCN or other classification systems.

Indicator 4: (MP-1.1.d) Extent of areas by forest type in protected areas defined by age class or successional state.

Indicator 5: (MP-1.1.e) Fragmentation of forest types.

Indicator 6: (MP-1.2.a) The number of forest dependent species.

Indicator 7: (MP-1.2.b) The status (threatened, rare, vulnerable, endangered, or extinct) of forest dependent species at risk of not maintaining viable breeding populations, as determined by legislation or scientific assessment.

Indicator 8: (MP-1.3.a) Number of forest dependent species that occupy a small portion of their former range.

Indicator 9: (MP-1.3.b) Population levels of representative species from diverse habitats monitored across their range.

CRITERION 2: Maintenance of productive capacity of forest ecosystems

Criteria Level Summary

Indicator 10: (MP-2.a) Area of forest land and net area of forest land available for timber production.

Indicator 11: (MP-2.b) Total growing stock of both merchantable and nonmerchantable tree species on forest land available for timber production.

Indicator 12: (MP-2.c) The area and growing stock of plantations of native and exotic species.

Indicator 13: (MP-2.d) Annual removal of wood products compared to the volume determined to be sustainable.

Indicator 14: (MP-2.e) Annual removal of non-timber forest products (e.g., fur bearers, berries, mushrooms, game), compared to the level determined to be sustainable.

CRITERION 3: Maintenance of forest ecosystem health and vitality

Criteria Level Summary

Indicator 15: (MP-3.a) Area and percent of forest affected by processes or agents beyond the range of historic variation, e.g., by insects, disease, competition from exoctic species, fire storm, land, clearance, permanent flooding, salinization, and domestic animals.

Indicator 16: (MP-3.b) Area and percent of forest land subjected to levels of specific air pollutants (e.g., sulfates, nitrate ozone) or ultraviolet B that may cause negative impacts on the forest ecosystem.

Indicator 17: (MP-3.c) Area and percent of forest land with diminished biological components indicative of changes in fundamental ecological processes (e.g., soil, nutrient cycling, seed dispersion, pollination) and/or ecological continuity (monitoring of functionally important species such as fungi, arboreal epiphytes, nematodes, beetles, wasps, etc.)

CRITERION 4: Conservation and maintenance of soil and water resources

Criteria Level Summary

Indicator 18: (MP-4.a) Area and percent of forest land with significant soil erosion.

Indicator 19: (MP-4.b) Area and percent of forest land managed primarily for protective functions (e.g., watersheds, flood protection, avalanche protection, riparian zones.)

Indicator 20: (MP-4.c) Percent of stream kilometers in forested catchments in which stream flow and timing has significantly deviated from the historic range of variation.

Indicator 21: (MP-4.d) Area and percent of forest land with significantly diminished soil organic matter and/or changes in other soil chemical properties.

Indicator 22: (MP-4.e) Area and percent of forest land with significant compaction or change in soil physical properties resulting from human activities.

Indicator 23: (MP-4.f) Percent of water bodies in forest areas (e.g., stream kilometers, lake hectares) with significant variance of biological diversity from the historic range of variability.

Indicator 24: (MP-4.g) Percent of water bodies in forest areas (e.g., stream kilometers, lake hectares) with significant variation from the historic range of variability in pH, dissolved oxygen, levels of chemicals (electrical conductivity), sedimentation or temperature change.

Indicator 25: (MP-4.h) Area and percent of forest land experiencing an accumulation of persistent toxic substances.

CRITERION 5: Maintenance of forest contribution to global carbon cycles

Criteria Level Summary

Indicator 26: (MP-5.a) Total forest ecosystem biomass and carbon pool, and if appropriate, by forest type, age class, and successional stages.

Indicator 27: (MP-5.b) Contribution of forest ecosystems to be the total carbon budget, including absorption and release of carbon (standing biomass, coarse wood debris, peat and soil carbon.)

Indicator 28: (MP-5.c) Contribution of forest products to the global carbon budget.

CRITERION 6: Maintenance and enhancement of long-term multiple socio-economic benefits to meet the needs of societies

Criteria Level Summary-Indicators 29-34 and 38 -41

Criteria Level Summary-Indicators 35-37 and 42-43

Criteria Level Summary-Indicators 44-47

Production and consumption

Indicator 29: (MP-6.1.a) Value and volume of wood and wood products production, including value added through downstream processing.

Indicator 30: (MP-6.1.b) Value and quantities of production of non-wood forest products.

Indicator 31: (MP-6.1.c) Supply and consumption of wood and wood products, including consumption per capita.

Indicator 32: (MP-6.1.d) Value of wood and non-wood products production as percentage of GDP.

Indicator 33: (MP-6.1.e) Degree of recycling of forest products.

Indicator 34: (MP-6.1.f) Supply and consumption/use of non-wood products.

Recreation and Tourism

Indicator 35: (MP-6.2.a) Area and percent of forest land managed for general recreation and tourism, in relation to the total area of forest land.

Indicator 36: (MP-6.2.b) Number and type of facilities available for general recreation and tourism, in relation to population and forest area.

Indicator 37: (MP-6.2.c) Number of visitor days attributed to recreation and tourism, in relation to population and forest area.

Investment in the forest sector

Indicator 38: (MP-6.3.a) Value of investment, including investment in forest growing, forest health and management, planted forests, wood processing, recreation and tourism.

Indicator 39: (MP-6.3.b) Level of expenditure on research and development, and education.

Indicator 40: (MP-6.3.c) Extension and use of new and improved technologies.

Indicator 41: (MP-6.3.d) Rates of return on investment.

Cultural, social and spiritual needs and values

Indicator 42: (MP-6.4.a) Area and percent of forest land managed in relation to the total area of forest land to protect the range of cultural, social and spiritual needs and values.

Indicator 43: (MP-6.4.b) Non-consumptive-use forest values.

Employment and community needs

Indicator 44: (MP-6.5.a) Direct and indirect employment in the forest sector and the forest sector employment as a proportion of total employment.

Indicator 45: (MP-6.5.b) Average wage rates and injury rates in major employment categories within the forest sector.

Indicator 46: (MP-6.5.c) Viability and adaptability to changing economic conditions, of forest dependent communities, including indigenous communities.

Indicator 47: (MP-6.5.d) Area and percent of forest land used for subsistence purposes.

CRITERION 7: Legal, institutional and economic framework for forest conservation and sustainable management

Criterion Level Summary-Indicators 48-52

Criterion Level Summary-Indicators 53-57

Criterion Level Summary-Indicators 58-59 and 60-62

Criterion Level Summary-Indicators 63-67

Extent to which the legal framework (laws, regulations, guidelines) supports the conservation and sustainable management of forests, including the extent to which it:

Indicator 48: (MP-7.1.a) Clarifies property rights, provides for appropriate land tenure arrangements, recognizes customary and traditional rights of indigenous people, and provides means of resolving property disputes by due process.

Indicator 49: (MP-7.1.b) Provides for periodic forest-related planning, assessment, and policy review that recognizes the range of forest values, including coordination with relevant sectors.

Indicator 50: (MP-7.1.c) Provides opportunities for public participation in public policy and decisionmaking related to forests and public access to information.

Indicator 51: (MP-7.1.d) Encourages best practice codes for forest management.

Indicator 52: (MP-7.1.e) Provides for the management of forests to conserve special environmental, cultural, social and/or scientific values.

Extent to which the institutional framework supports the conservation and sustainable management of forests, including the capacity to:

Indicator 53: (MP-7.2.a) Provide for public involvement activities and public education, awareness and extension programs, and make available forest related information.

Indicator 54: (MP-7.2.b) Undertake and implement periodic forest-related planning, assessment, and policy review including cross-sectoral planning and coordination.

Indicator 55: (MP-7.2.c) Develop and maintain human resource skills across relevant disciplines.

Indicator 56: (MP-7.2.d) Develop and maintain efficient physical infrastructure to facilitate the supply of forest products and services and support forest management.

Indicator 57: (MP-7.2.e) Enforce laws, regulations and guidelines.

Extent to which the economic framework (economic policies and measures) supports the conservation and sustainable management of forests through:

Indicator 58: (MP-7.3.a) Investment and taxation policies and a regulatory environment which recognize the long-term nature of investments and permit the flow of capital in and out of the forest sector in response to market signals, non-market economic valuations, and public policy decisions in order to meet long-term demands for forest products and services.

Indicator 59: (MP-7.3.b) Non-discriminatory trade policies for forest products. Capacity to measure and monitor changes in the conservation and sustainable management of forests, including:

Indicator 60: (MP-7.4.a) Availability and extent of up-to-date data, statistics and other information important to measuring or describing indicators associated with criteria 1-7.

Indicator 61: (MP-7.4.b) Scope, frequency and statistical reliability of forest inventories, assessments, monitoring and other relevant information.

Indicator 62: (MP-7.4.c) Compatibility with other countries in measuring, monitoring and reporting on indicators.

Capacity to conduct and apply research and development aimed at improving forest management and delivery of forest goods and services, including:

Indicator 63: (MP-7.5.a) Development of scientific understanding of forest ecosystem characteristics and functions.

Indicator 64: (MP-7.5.b) Development of methodologies to measure and integrate environmental and social costs and benefits into markets and public policies, and to reflect forest related resource depletion or replenishment in national accounting systems.

Indicator 65: (MP-7.5.c) New technologies and the capacity to assess the socioeconomic consequences associated with the introduction of new technologies.

Indicator 66: (MP-7.5.d) Enhancement of ability to predict impacts of human intervention on forests.

Indicator 67: (MP-7.5.e) Ability to predict impacts on forests of possible climate change.

SCIENCE REVIEW SUPPLEMENT

As part of the LUCID Project, we asked a team of sustainability and monitoring science specialists to participate in the scientific review of the final draft project report. Specifically, science specialists were asked to review the final LUCID report and address the following areas:

- Scientific adequacy of the project in addressing the original objectives;
- Identification of subject areas within the report for clarification and further development;
- The utility and scientific validity of the approach taken in the LUCID Project for Forest Management Unit scale C&I development with specific attention to the areas of innovation;
- Suggestions for implementation of a LUCID (FMU) type approach;
- Recommend areas for further work and research; and
- Scientific limitations of the LUCID approach in providing the Forest Service and its managers with an effective FMU-scale C&I mechanism to assess sustainability and respond through adaptive management.

OVERALL FINDING

Scientific reviewers confirmed the adequacy of the LUCID Project and made a number of key recommendations for suggested changes to the report. Synthesized comments are described below in the six major review areas followed by a summary of the changes that were incorporated into the final LUCID report.

SCIENTIFIC ADEQUACY AND APPROACH

Review Comments

Reviewers noted that the LUCID Project was an applied research project. Reviewers reported a thorough job of evaluating and documenting the process of developing and testing a set of C&I for FMU-scale sustainability. Specifically reviewers noted that:

- The methodological approach of the LUCID Project did a good job at acknowledging the values that underlie the discussions of sustainability;
- There was significant value in a monitoring process that used C&I tools to help enable learning;
- The application of a systems approach was one of the areas of significant scientific improvement over many existing monitoring approaches;
- The application of a systems approach in LUCID was a good first step. They also suggested that there were some next steps that should be taken during implementation in order to carry the application of a systems approach further;
- The social framework was critiqued as encompassing too broad an array of social well-being conditions by one reviewer (without adequate justification and explanation) and by another as including appropriate elements of social dimensions (but wanting more expansion on some of these).

Reviewers noted areas for suggested improvement included:

- More discussion of associated scientific literature;
- Less discussion of associated scientific literature;
- Expansion of the applied research component of the methodology; and
- Experimentation with alternative approaches and designs for analysis.

LUCID Response

The systems approach served as the framework for the LUCID Project. We agree with reviewers that this is a valuable first step in moving complex systems theory into practice. We concur that there is still much work to be done in this regard but reiterate that LUCID participants found that the general approach and framework was a substantial improvement over existing frames of reference. Communicating these complex ideas within a few pages was a particular challenge. We note that there is significant work needed in communicating the idea and approach of systems to the Forest Service.

Based on review comments we were able to clarify and improve on some of our explanations of ecological systems particularly in the areas of constraints, resiliency and fragility.

We recognized that there were still strong differences of opinion as to the scope of social systems that should be included in such a sustainability initiative. Based on review comments we were also able to strengthen our explanation of the social system framework. The social systems framework revised in the LUCID Project was, however, retained as it was found to have value and utility to LUCID participants. We recognize, however, that like the ecological systems framework, the social framework is in need of further research and development (Chapter 1, 7 and 8).

The LUCID Project did not set out to test a series of rival or alternative methodologies for analytical design and tools although alternative approaches were discussed and examined where available. We concurred with reviewers that although the analytical approaches used during the LUCID Project are an improvement upon existing approaches there is a need for further research and development. The report profiles the need for further research and specifically the pursuit of alternative analytical approaches and tools that might tested during phased implementation. A national technical assistance group, internal and external specialists in systems and analytical approaches could pursue strengthening the analytical approaches (Chapter 12, 13 and 15).

IDENTIFICATION OF AREAS FOR DEVELOPMENT AND CLARIFICATION

Review Comments

Reviewers identified a number of areas within the report for further development or clarification including:

- A need to more clearly differentiate between the process (the approach) the results of the project;
- One reviewers desire for the addition of a specific definition of sustainability;
- A stronger explanation and justification of social indicators and framework.

- The desire to see the details on the measures including a description, potential data sources and data availability;
- A restructuring of the analytical tools section to move some of the "how to" detail into the appendixes or out of the report and to concentrate on an evaluation of the attributes of the tools;
- A discussion of alternative analytical approaches;
- Specific comments and suggested changes to discussions of systems and scale specifically related to fragility, perspective and sustainability.
- One reviewer also noted a desire for additional information on what has changed on the six forests as a result of the test.

LUCID Response

In response to the review comments we made a number of changed to the report to either add new material or to give existing material a higher profile in the report.

We agreed with reviewers comments regarding a need to differentiate more clearly between "process" and "product" in the report and reorganized using a set of common subheadings to differentiate between process and results (products).

Detailed information on the measures that reviewers wanted is available in an electronic database (the LUCID C&I Resource Database). As a result of the reviewers comments we expanded the discussion of measures in chapter 9 to provide a broader explanation of the kinds of information associated with measures. The LUCID Resource Database (available electronically only as Appendixes 9) was profiled more prominently both in chapter 9 and also in the previous chapters (7-8).

We incorporated reviewer comments regarding our explanations of system fragility, resiliency and sustainability and the roles of perspective.

Although we differed in perspective from one of the reviews on social systems as a result of the reviewer's comments we were able to expand the explanation and provide additional information on social criteria and indicators.

As a result of this review, we reaffirmed the value of working collaboratively with others to define place-based understandings of sustainability through the use of C&I.

The analytical tools chapter (13) was revised to move much of the 'how to' material and some of the details to appendixes. The reorganization focused on the key features desired in tools for analysis and synthesis and was structured to include a description of the feature and evaluation of its application within the LUCID Project. Alternative approaches and methodologies were profiled as available.

In response to requests for additional information on "what has changed" as a result of the test we provided additional profiles of the experiences of the LUCID forest teams from the perspectives of the forest supervisors and the team members. As LUCID forests participated in the project in a pilot test fashion full implementation of the results has not yet happened. Some of the LUCID forests are using the information or the general approach in preparation for upcoming forest plan revisions and others for specific projects. We agree that the reviewers request for additional information on "what has changed" would be very useful and will provide additional updates on the application of the material on the IMI website as time progresses.

AREAS OF INNOVATION

Review Comments

Reviewers noted the principle areas where the LUCID Project contributed to the more general study and application of C&I including:

- The value of a systems approach and a systems framework as a guide for indicator development and analysis;
- The development and testing of reference values as the next step in C&I methodology with specific note given to the documentation on the lessons learned about reference value development;
- The pursuit of analytical approaches in keeping with the system framework;
- The testing of C&I across a range of conditions with a consistent methodology;
- The learning approach and collaboration between staff and others that demonstrated the value of learning together about sustainability; and
- The value of demonstrating the benefits of FMU-scale C&I and the value of developing them in a more bottom-up, experiential manner.

LUCID Response

We appreciate the reviewers perspectives and examined the report to ensure that the areas of innovation or key contribution were adequately described.

ORGANIZATION AND PRESENTATION

Review Comments

Reviewers made a number of comments about the challenges of navigating through a lengthy report, repetitions in the text, the mix of product and process elements, and the resulting challenges in uncovering the major points and findings. Specific editorial suggestions were also made.

LUCID Response

As a result of the reviewers detailed comments we re-envisioned the report as both the final report of the LUCID Project and a desk reference for FMU-scale sustainability monitoring. In addition to a rewrite to remove redundancies and clear up confusion we added the following organizational devices to help the reader navigate through the document and find the areas of interest (see the report preface ‘Guide to Users’):

- An executive summary geared towards management implications;
- A “Guide to the Report” to describe the components;
- Five distinct sections in the report;

- Individual chapter tables of contents with brief descriptive statements of the major headings in each chapter;
- Chapter highlights at the end of the major chapters that summarize the major points and within chapter key findings;
- For the major results chapters (6-11) we applied common headings (Background, Process, LUCID Experience, Implications) to help the reader focus on areas of interest;
- Removal of some technical material to the appendixes; and
- The entire report was also technically edited.

RECOMMENDED AREAS FOR FURTHER WORK AND RESEARCH

Review Comments

Reviewers recommended a number of areas for further development or research including:

- Evaluation of the added value that sustainability monitoring provides to management including testing the extent to which it facilitates the exchange of information horizontally among forests and vertically up the hierarchy;
- Continued research and development of analytical tools and approaches;
- Further application of systems approaches to monitoring and management throughout the Forest Service;
- Continued development of social measures with more focus on qualitative approaches; and
- Further research on social indicators and social systems frameworks for sustainability in particular the bounds of the social system with respect to sustainability.

LUCID Response

Many of the areas that the reviewers recommended for further research had already been included in the report; however, as a result of the review comments we were able to profile these more clearly.

We concur with the suggestion to evaluate the overall utility of C&I as a monitoring tool. Such an approach would be consistent with the idea of a phased implementation approach FMU-scale sustainability monitoring and the establishment of a core technical assistance group (Chapter 15).

SUGGESTIONS FOR IMPLEMENTATION

Review Comments

Reviewers made a number of specific suggestions about implementation of FMU-scale sustainability monitoring:

- Reviewers suggested that implementation of FMU scale sustainability monitoring was an approach worth pursuing as a potential substitute for monitoring in the land management planning process.
- Reviewers expressed implementation concerns about the feasibility of implementation specifically issues of data availability, costs of monitoring, and about the readiness of all of the measures.
- A suggestion was made to prepare a simple "how to" package and a web-based reference resource to aid implementation.

LUCID Response

Implementation issues including data availability, consistency and flexibility concerns, costs and the availability of measurement protocols are discussed in the report. We concur with the reviewers that additional implementation information is still needed and the report recommends a series of steps including the preparation of a business requirements model for sustainability monitoring to help detail the costs and a phased implementation approach. Such an approach would allow data availability, costs and other feasibility issues to be examined more closely under the revised methods and revised frameworks.

We concur with reviewers on the need to provide assistance and to facilitate implementation in an easily accessible way. The initial steps have been taken to develop the basis of a "how to" and web-based reference package including identification of the primary steps in the process, case study examples from the Forests' experiences, and the C&I Resource Database. Web-enabling this would be relatively straightforward and there are several other initiatives with similar approaches (see Chapter 15) that can serve as models.

REVIEWERS

Dr. Timothy Allen, Professor, Department of Botany, University of Madison, Wisconsin

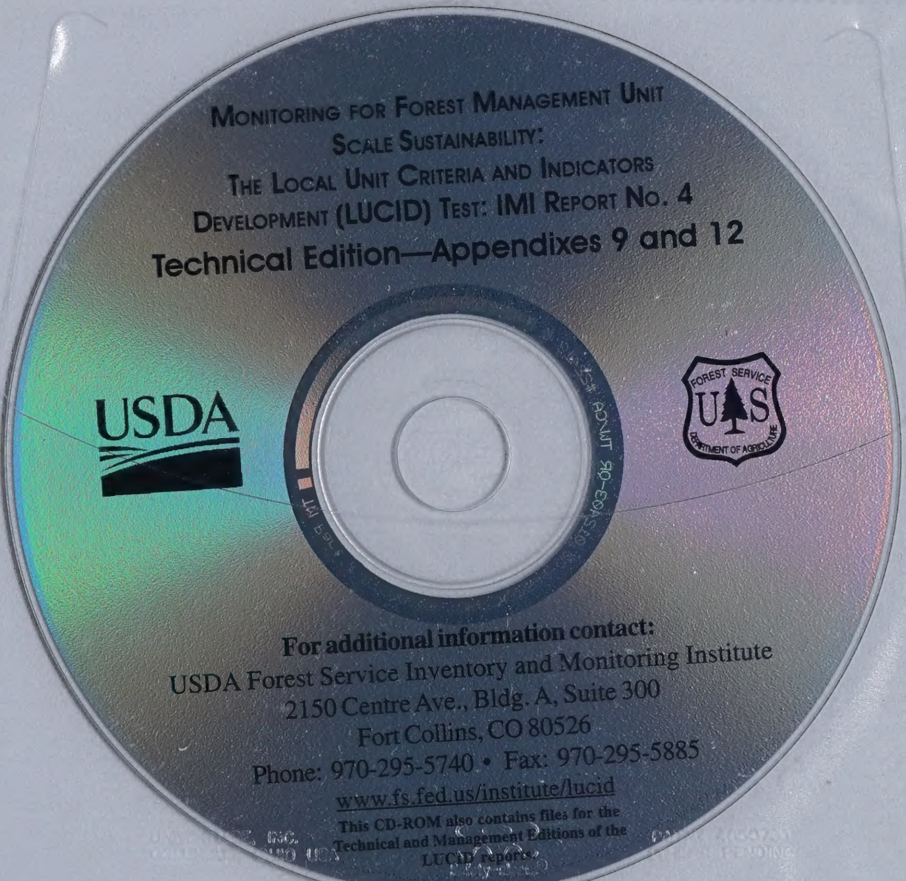
Dr. James J. Kay, Professor, Environment and Resource Studies, University of Waterloo

Dr. Donald W. Floyd, Professor, Faculty of Forestry, State University of New York

Dr. Ravi Prabhu, CIFOR, Harare, Zimbabwe

Dr. Joseph A. Tainter, Project Leader, Cultural Heritage Research, USDA FS Rocky Mountain Research Station, Albuquerque Lab.

Dr. Stephen Woodley, Chief Scientist, Parks Canada



MONITORING FOR FOREST MANAGEMENT UNIT
SCALE SUSTAINABILITY:
THE LOCAL UNIT CRITERIA AND INDICATORS
DEVELOPMENT (LUCID) TEST: IMI REPORT NO. 4
Technical Edition—Appendixes 9 and 12

USDA

FOREST SERVICE
U S
DEPARTMENT OF AGRICULTURE

For additional information contact:
USDA Forest Service Inventory and Monitoring Institute
2150 Centre Ave., Bldg. A, Suite 300
Fort Collins, CO 80526
Phone: 970-295-5740 • Fax: 970-295-5885
www.fs.fed.us/institute/lucid

This CD-ROM also contains files for the Technical and Management Editions of the LUCID reports.

The United States Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, sex, religion, age, disability, political beliefs, sexual orientation, or marital or family status. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA's TARGET Center at (202) 720-2600 (voice and TDD).

To file a complaint of discrimination, write USDA, Director, Office of Civil Rights, Room 326-W, Whitten Building, 1400 Independence Avenue, SW, Washington, DC 20250-9410 or call (202) 720-5964 (voice or TDD). USDA is an equal opportunity provider and employer.

Printed on recycled paper